Performance Investigation of Simulation Models of Wireless Mobile Ad Hoc Networks

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Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the Degree of

Master of Science
in
Computer Engineering

Eastern Mediterranean University
January 2010
Gazimagusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

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ABSTRACT

Wireless ad hoc networks have attracted great interest in last few years, due to envisioning of their great potential in military and commercial applications. Being a wireless network of mobile computing devices that doesn't rely on any pre-established infrastructure, they eliminate the complexity of infrastructure setup. Accordingly become popular in several application areas, such as battlefields, emergency areas, wireless sensor networks and hybrid wireless networks and can be deployed anywhere at anytime.

This thesis provides a Petri-net-based model of a wireless ad hoc network, where all fundamental aspects with the proposed, a general and more realistic, inter-node communication scheme are implemented. The model is implemented in terms of extended Petri nets and the simulation system Winsim is used in development and simulation. There are two types of modules in the model, namely node and switching module, that is, the model is organized in a multi-module system.

Three fundamental performance metrics of an ad hoc network – packet delivery ratio, average number of hops and relative network traffic – were investigated under different transmission radius, model parameters and conditions of mobility model and inter-node communication scheme.

The entire model, together with the proposed inter-node communication scheme can be used for study of routing protocols as well as other aspects of information transmission in wireless ad hoc networks. The further study of this thesis can be the

development of an efficient routing protocol that results in reduced network load and energy usage at mobile nodes as well as increasing the security of the network.

The thesis is organized as follows. Chapter 1 introduces the era of computer and wireless networks, with the problem and statement of the work goal of the thesis. Chapter 2 provides a survey of the existing methods and tools for modeling and simulation of wireless ad hoc networks. Chapter 3 is devoted to the specification of system assumptions and the chosen mobility model. Chapter 4 explains the proposed scheme of inter-node communication. In Chapter 5, the organization and components of the entire model is considered. Chapter 6 describes the simulation setup and results of simulation. Chapter 7 concludes the thesis.

Keywords: Mobile wireless ad hoc networks, oriented links, simulation, extended Petri nets, mobility models.

ÖZ

Son yıllarda, kablosuz ve alt yapısız ağlar insanlar arasında büyük bir ilgi uyandırmıştır. Bunu da bu ağların askeri ve ticari alanda kullanılan uygulamalardaki görülen büyük potansiyeline bağlayabiliriz. Hiçbir alt yapıya dayanmayan kablosuz ağlar olmakla birlikte, mobil hesaplama cihazlarının kurulumundaki bütün alt yapı güçlüklerini ortadan kaldırması; bu ağların popülaritesini birçok alanda artırmıştır. Buna örnek olarak da; savaş alanları, acil-olağanüstü durum alanları, kablosuz alıcı ağları ve hibrit kablosuz ağlarda artırdıklarını söyleyebiliriz. Ayrıca her an, her yerde kurulabilecek bir ağ türü yaratmıştır.

Yapılan bu tez çalışmasında Petri-net esaslı bir kablosuz alt yapısız ağ modeli sağlanmaktadır. Modelde bahsedilen ağların bütün ana konularıyla birlikte genel ve daha gerçekçi bir devre-arası iletişim taslağı da uygulanmıştır. Simulasyon için kullanılan Winsim sistemi, bu genişletilmiş Petri-net cinsinden yapılmış modelin geliştirilmesinde ve simule edilmesinde kullanılmıştır. Bu model birden çok modüllü bir sistem olarak düzenlenmiştir. İlk modül tipi node (devre) ve ikinci modül tipi ise switching (anahtarlama) modülüdür.

Alt yapısız ağlar üç ana performans ölçü birimini ile incelenmektedir. Bunlardan bir tanesi paket teslim oranı, ikincisi; ortalama sekme sayısı ve , son olarak ta göreceli trafik'tir. Bu ölçü birimleri değişen aktarım yarıçapı, model parametreleri ve hareketlilik modeli ile devre-arası iletişim taslağı koşulları altında incelenmiştir.

Bütün model, önerilen devre-arası iletişim taslağı ile birlikte kablosuz altyapısız ağlarda yönlendirme protokolleri ve diğer bilgi iletişimi/dağılması ile ilgili konulardaki çalışmalarda da kullanılabilir. Bu tez çalışmasının daha ileride ki çalışması ise, ağdaki yükü ve mobil devrelerdeki güç kullanımını azaltıp, aynı anda ağın güvenliğini artıracak olan verimli bir yönlendirme protokolü üzerinde olabilir.

Bu tez çalışmasının organizasyonu şu şekildedir: 1. bölümde, bilgisayar ve kablosuz ağların devrimiyle birlikte tezin ele aldığı problem ve amacı açıklanmaktadır. Kablosuz altyapısız ağların modelleme ve simulasyonlarında kullanılan metodların ve araçların araştırması 2. bölümde açıklanmıştır. 3. bölümde ise, geliştirilen bu sistemdeki varsayımların ve seçilen hareketlilik modeli belirtilmiştir. Bütün modelin düzenlemesini ve parçaları 5. bölümde ele alınmıştır. 6. bölümde ise simulasyon düzeni ve sonuçları açıklanmıştır. Son bölümde de tez sonuçlandırılmıştır.

Anahtar kelimeler: Mobil kablosuz alt yapısız ağlar, yönlü bağlantılar, simulasyon, genişletilmiş Petri-net'ler, hareketlilik modelleri.

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Chapter 1

INTRODUCTION

Before 1970's computing and communication fields are thought as two separate independent fields. However in late 1970's and early 1980's, with the envisioning of the great possibilities enabled from harmonization of these two fields, the computing and communication field is merged. This results in so called computer networks.

A computer network is defined as a group of interconnected autonomous computers/nodes that each participating computer aids from this communication in variety of ways. Improved reliability of services, ensured good communication medium, cost effectiveness and sharing of available resources are some of the advantages gained.

Modern-day computer networks are composed of two major units, namely distributed applications and networking infrastructure. Distributed applications are used to enable services, such as internet, e-mail and banking systems, to users/applications and almost indispensable from our every day life. While networking infrastructure is responsible for providing the data transfer. The physical media used to provide connectivity is not restricted and can be in different forms, such as copper cable, optic fiber or wireless radio waves. This thesis will focus on wireless networking, and in particular wireless ad hoc networks, where wireless radio waves are the physical media used.

In 1897, Guglielmo Marconi invented the world's first wireless radio communication system. And consequently, was able to transmit radio signals across the Atlantic Ocean from England to America (approximately 1700 miles) in 1901. This is counted as, the successful demonstration of his wireless telegraph system and indicated the beginning of the radio communications era.

Wireless networks can be declared as computer networks, which use electromagnetic radio waves to communicate. Each node willing to communicate with some other node in the network broadcasts information over the air. This information can be received by all nodes/central stations in the transmission radius of the sender and can be delivered to the receiver directly (if in the transmission radius of the sender) or relayed to the next point of communication till delivered to the destination. Therefore there is no need for nodes to be physically connected to a network, which allows them to be mobile.

Being one of the fastest growing industries, wireless communications are very popular in every part of our life, where information communication is involved. Wireless ad hoc networks are one of the fastest emerging type of wireless networks.

Multi hop relaying is the principle behind ad hoc networking. The traces of this principle reaches back to, 500 B.C., Darius I. He was the king of Persia and inventor of this new communication system that uses a sequence of shouting man located at tall structures or heights to deliver messages from his capital to remote countries of his empire. This system was used by many other ancient societies as well, to deliver their messages through a line of repeaters, such as drums or horns [1].

The invention of ALOHAnet [2], the packet radio network (PRNET) project [3] and the survivable radio networks (SURAN) project [4] sponsored by DARPA,

formation of the mobile ad hoc networks (MANET) working group [5] and the Bluetooth project of the Swedish communication equipment maker Ericsson, which is later taken over by the Special Interest Group (SIG) [6] can be considered as some important but not all milestones that formalizes the definition of wireless ad hoc networks of today.

A Wireless ad hoc network is defined as a spontaneous network of mobile nodes, which are connected through wireless links. These networks, being ad hoc, does not rely on pre-established infrastructure, such as base stations in cellular networks, which makes them rapidly deployable and flexible (anyplace, anytime connectivity). Lack of any centralized coordination point, decentralized environment of the network, forces mobile nodes to coordinate among themselves for communication. Consequently each node is expected to act as a router, by participating in communication of other nodes as an intermediate node, apart from being a source or destination. In other words, routing functionality should be integrated into mobile nodes instead of centralized points of communication. As in definition, nodes are connected through wireless links and being independent, they are free to move in any direction, with the desired and usually different speed. This independent mobility, results in unpredictable and frequent topology changes, which makes routing and information transmission in wireless ad hoc networks a challenging task.

The main application areas for wireless ad hoc networks are in variety, ranging from battlefields, disaster areas, wireless sensor networks, collaborative and distributed computing to hybrid (integrated cellular and ad hoc wireless networks) wireless networks. Despite the fact that wireless ad hoc networks are known to work in case of shortage of any pre-established infrastructure. They are started to be used in case of

presence of infrastructure as well, namely at hybrid architectures, where benefits of cellular and ad hoc networks are combined.

Despite all the developments, many challenges of wireless ad hoc networks such as, unreliability of wireless communication, mobility caused unpredictable and frequent route changes and packet losses, preservation of security and resource constraints makes successful commercial deployment of these networks not possible for today. Where more research is still required for development of efficient and practically feasible schemes of various aspects of wireless ad hoc networks. In order to contribute in this progress, we have set the main goal of this thesis in three-fold. First, it proposes a novel inter-node communication scheme that is proposed by our research group and reflects the reliability aspects of wireless communications, such as interference, fading effects, presence of obstacles and weather conditions in a general and feasible way. Second goal is to investigate three fundamental performance metrics of a wireless ad hoc network that reflects important characteristics of such networks under various conditions of chosen mobility model and proposed inter-node communication scheme. And the third goal of this thesis is to show, how the entire model can be represented with the use of Petri nets.

The developed model was investigated by simulation modeling, which is one of the two main directions to examine wireless ad hoc networks. A number of popular simulation packages such as, NS2, OPNET, JavaSim, OMNet++ and SSFnet, are available for performance evaluation of data processing system. Due to some important drawbacks, such as not reflecting concurrency of events and process in networks in a clear way, the fundamental information on how the simulation system works being deeply hidden and not accessible by the user and generation of large programs that are

hard to analyze, understand and update are directed us to use the simulation system Winsim for the development and simulation of the model. The model developed in this thesis is implemented in terms of extended Petri nets, which is one of the most popular techniques to model and analyze concurrent and distributed systems.

Chapter 2

SURVEY OF THE EXISTING METHODS AND TOOLS FOR MODELING AND SIMULATION OF WIRELESS AD HOC NETWORKS

2.1 Main Directions to Investigate Wireless Ad Hoc Networks

Wireless ad hoc networks are investigated under two main directions. The first direction is related to deployment of such networks in real-world outdoor environments, namely experimental studies. It requires large resources, long time and many participants to perform such studies. The lack of repeatability is another drawback of the experimental studies, that is, the behaviour of the investigated network can not be evaluated many times with exactly same environmental effects. However this approach provides very valuable information about actual characteristics of wireless ad hoc networks. And since there is no potential to have inaccurate or wrong assumptions about external influences, more realistic output data is obtained as well. A survey of existing real-world ad hoc test beds is given in [7].

The second direction is related to simulation modeling. Simulation modeling is an attempt to form a simplified abstraction of a real system at a digital computing environment, so that the system can be studied to investigate its behaviour, under

various conditions, and gain insights on how the system operates [8]. In order to make clear and solidify the definition of simulation modeling, descriptions of what a real system, model of a system and discrete-event system simulation are provided with the following text.

A real system can be defined as, a set of elements that interacts with each other to perform some common task. Considering dynamic systems, continuous and discrete systems are the main categories. In continuous systems, state variables, variables that are chosen to describe the behaviour of the system, are continuously changing in time and taking continuous values. However, in discrete systems, state variables are changing at discrete moments of time and only take discrete values [8].

A simplified abstraction of a system that is detailed enough to allow the derivation of desired performance measures with sufficient accuracy is called a model of the system. Models can be static/dynamic, deterministic/stochastic and continuous/discrete. The simulation model that, this thesis considers is categorized as a dynamic, stochastic and discrete model, which belongs to, so called, discrete-event simulation models. More comprehensive information about systems, models and simulation can be found in [9].

Discrete-event simulation is the modeling of a system with instantly changing state variables, at discrete set of points in time, as the system progresses over time. These points are the points where an event, an instantaneous activity that usually alters the system's current state, occurs. During the run of a model, an artificial history of the model, based on the model assumptions, is generated and via applying the system parameters, raw output data of the simulation run is collected for analysis and investigation of system's performance. Since the mount of data stored, manipulated and

provided as output is in large amounts, computers are used to conduct runs of models [10]. The software programs (simulation packages), used on computers, to simulate an abstract model of a real system for investigation of its performance characteristics can be very beneficial when applying some changes to existing protocols or testing of new protocols as physical deployment of actual systems (can be very expensive or maybe not even possible) is not necessary. Furthermore, simulation modeling has other great advantages, such as:

- requirement for much fewer resources (participants, time and equipments) as compared to the experimental studies,
- manageability of time (time can be easily compressed/expanded),
- competence to investigate behaviour and characteristics of ad hoc networks with arbitrary large number of mobile nodes and any desired combination of parameters.
- being the only type of investigation possible, for most complex, real-world systems with stochastic elements, since they can not be accurately described by a mathematical model for analytical evaluation,
- usability to answer "what if" questions,
- ability to test different modes of operation outside the real system, without disturbing ongoing operations, in the analysis of an existing system, and
- ability to check design variants before implementation in the design of new systems [11], [10].

Beside these advantages, simulation modeling also has its problems and challenges. Model building requires special training and experience, in order to be able

to develop accurate models. Where in our model, choosing sufficiently realistic mobility model for node movement, specifying a general and feasible scheme of inter-node communication and determining reasonable performance metrics that reflect important characteristics of the network, as well as, how to derive these metrics from the raw simulation data, are some of the complexities that we, as the developer, should meet before modeling. After modeling and run of simulation, the obtained results can be difficult to interpret, as the output results are random. Accordingly it is hard to determine if an observation is a result of randomness or system interrelationship [8].

2.2 Tools for Modeling and Simulation of Wireless Ad Hoc Networks

Among number of simulation packages available, NS2 and OPNET are two of the most popular tools used for modeling and simulation of wireless ad hoc networks. NS2 is a discrete event network simulator that is generally used in simulation of routing and multicast protocols as well as ad hoc networks. User provides a network topology through the simulation interface, using OTcl scripts. Then the program, using specified parameters, simulates the provided topology. Support for popular network protocols is counted as one of the major advantages of NS2. However the simulator has incomplete wireless MAC/PHY layer definition that modelling of obstacles is unaccomplished.

OPNET is another event based network level simulation tool. Simulation of fixed or wireless networks as well as heterogeneous networks with various protocols is possible with the use of OPNET. High level interface of the tool enables an easy interaction to the system. But problems with modeling network traffic and lack of truthful attack models are the major drawbacks with OPNET.

On the other hand, Petri nets are one of the most popular techniques to model and analyze concurrent and distributed systems. They are very powerful mathematical and graphical tools that can formally describe and model systems, but not an algorithmic system, that is, the Turing machine [12] can not be represented with the use of original Petri nets. Accordingly they can not be used for simulation purposes. To overcome this drawback several extensions and modifications of original Petri nets are available.

Evaluation nets (E-nets) is one known class of extended Petri nets, which targets important but absent concepts of original Petri nets, such as notion of time, attributed tokens, control functions and transformation of token attributes. Furthermore, E-nets functioned as an initial point for the development of more powerful class of extended Petri nets, where new features such as unlimited number of input and output places for transitions (enabled through elementary nets), queue places that allows arbitrary large number of tokens and a new elementary net named as an interruptible net was introduced. Introduction of these new features combined advantages of general Petri nets and high level programming languages, which makes extended Petri nets a suitable and efficient tool for simulation purposes. The methodology of modeling and simulation with extended Petri nets can be obtained from [13].

More broad information about extended Petri nets and the simulation system used are provided at the continuation of this chapter.

2.3 Extended Petri Nets for Simulation

As in classical Petri nets, the minimal structural elements of extended Petri nets are places, transitions and directed arcs. There are two types of places, which are simple and queue places. Simple places are represented as circles and can only hold one token

at a time, where queue places are represented with ovals and can hold unlimited number of tokens at a time. The behaviour of any Petri net model can be expressed with the use of its transitions. Firing of transitions and subsequent movement of corresponding tokens from fired transition's input places to output places will represent the behaviour of that Petri net. Places and transitions are connected according to the rules of bipartite directed graph with the use of directed arcs.

Minimal, functionally complete, structural components of extended Petri nets are elementary nets, which are used to consider the underlying processes of the modelled system. An elementary net $E(t)$ of a transition t can be formally defined with the following expression:

$$E(t) = < C, P1 , P2, r1, r2, d, m >, \quad (2.1)$$

where; C is a necessary (but generally not sufficient) condition to fire transition t; $P1$ and $P2$ are finite sets of input and output places for t, with $P1 \cap P2 = \varnothing$ and $P1 \cup P2 \neq \varnothing$; $r1$ and $r2$ are functions of input and output selection respectively; d is a delay function; and m is a data transformation function.

Many possible structures of elementary nets are available, but in order to model any data processing system, in terms of extended Petri nets, it is sufficient to only use basic set of types of elementary nets shown in Fig. 2.1. This statement is proven with the work in [14]. Three types of these basic elementary nets, namely Type T, Y and X, is used in the developed simulation model of wireless ad hoc networks. Elementary net of type T can be used for joining and forking of tokens, together with transformation of token attributes and associated time delay. Elementary net of type Y applies conditional selection to one of the input places of a transition, where a token will be removed and

added to each of the output places. Elementary net of type X provides conditional selection of one of the output places, where a token will be routed.

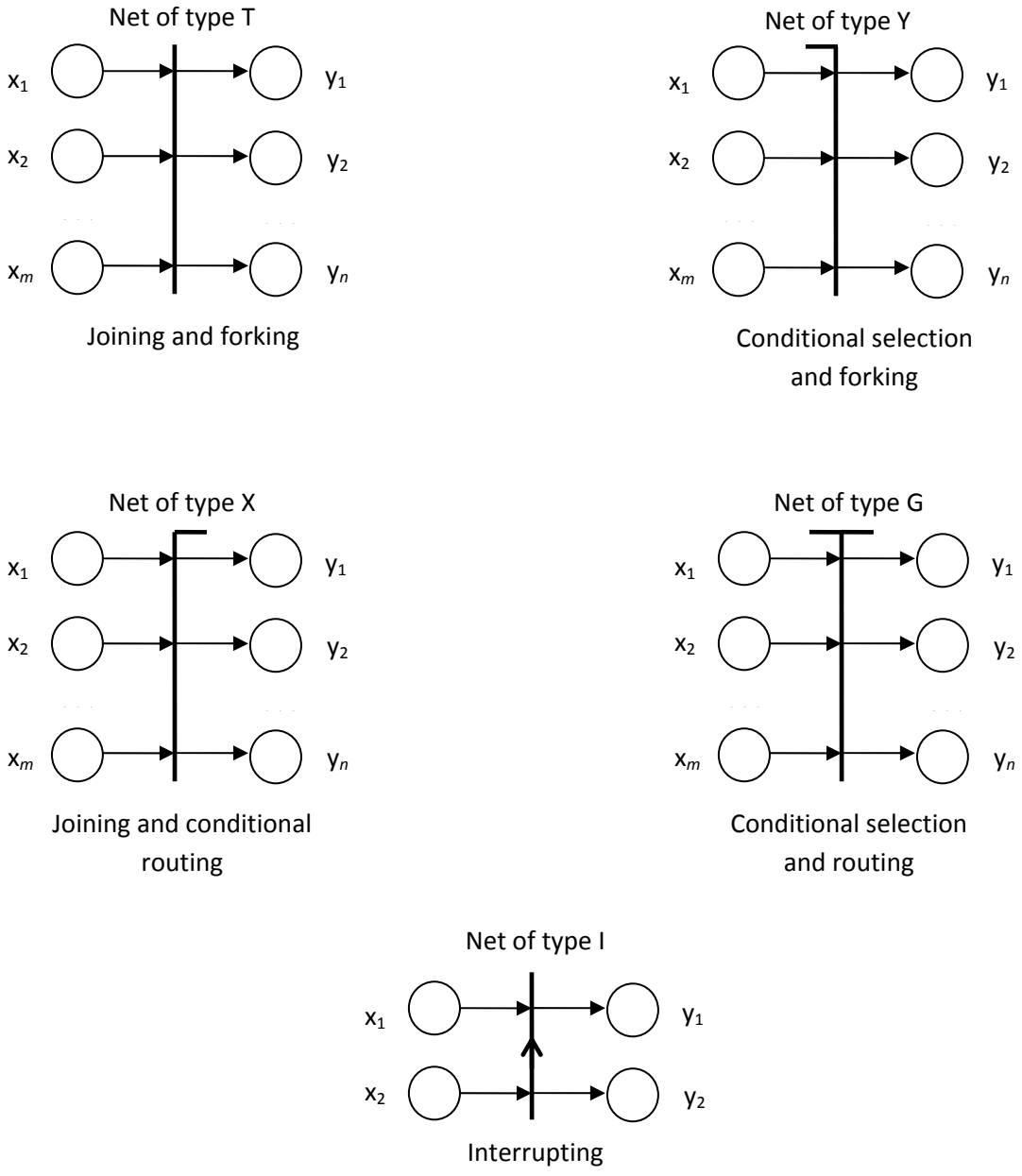

Figure 2.1 : Elementary nets of extended Petri nets.

2.4 Simulation System Winsim and Model Description Language

Modelling and simulation of the entire model, of the wireless ad hoc network, investigated in this thesis, is done with the use of the simulation system Winsim. Simulation system Winsim is based on a class of extended Petri nets and can be used for performance evaluation of parallel and distributed systems via simulation modeling. Moreover it provides high level programming language possibilities for complex data processing. The increased efficiency of extended Petri nets for simulation purposes, high-level timed coloured Petri nets with simple and queue places, attributed tokens and fixed set of basic elementary nets are the features enabled through the extended Petri nets that are used in Winsim. All these features make Winsim an easy to use and fast modeling tool [15].

During the creation and run of models, represented in terms of extended Petri nets, Model Description Language (MDL) and Modeling Control Language (MCL) are the main tools used by us, the developer, to interact with the simulation system Winsim.

Using MDL, any Petri-net-based simulation model and its components can be expressed as a sequence of statements, called a segment. A complete model is made up of one or more segments, where the notion of a segment in MDL is akin to the notion of a module in an ordinary programming language. More to the point each segment is a complete unit of work for MDL compiler. Attributed tokens moving from one segment into another via external places enable information links between segments and make the communication possible.

All the power of Pascal to process data is available within the MDL, as it is implemented as an extension of Object Pascal Language. Declarations of token

attributes, descriptions of elementary nets, statements for attaching and linking segments are elements of the extension. The MDL fragment of the switching segment of the developed model is shown in Fig. 2.2.

Any kind of user interaction with the ready model, such as setting an initial state of the model, monitoring and controlling of the simulation run can be handled with the use of MCL. It can be used before or during the run of a ready model and in interactive command line or batch mode to input MCL statements. A fragment of MCL code used in the developed model is shown in Fig. 2.3.

```
SEGMENT SWITCH, TICK = SEC;
ATTRIBUTES
   MTYP: INTEGER;                                    (* Message type: *)
   SRC : INTEGER;                                  (* Source node of message *)
   DEST: INTEGER;                               (* Destination node of message *)
   SNDR: INTEGER;                        (* If MTYP > 1, sending node of this msg *)
   NEXT: INTEGER;                                (* Next node to pass message *)
   MID : INTEGER;                          (* Msg Id: 1, 2, ... ; incremented by src *)
   NONB: INTEGER;                      (* The number of next nodes to pass msg *)
   XCD : REAL;                                     (* X-coordinate of sender *)
   YCD : REAL;                                     (* Y-coordinate of sender *)
   TTL : INTEGER;                        (* Max number of hops for msg to pass *)
   HOPS: INTEGER;                         (* Number of hops passed by message *)
   .   .   .   .   .   .   .
   ND12: INTEGER;
DATA
   NODS /0/: INTEGER;                    (* Given number of nodes in the area *)
   XMIN /0.0/: REAL;                      (* Minimal X-coordinate of the area *)
   XMAX /0.0/: REAL;                     (* Maximal X-coordinate of the area *)
   YMIN /0.0/: REAL;                      (* Minimal Y-coordinate of the area *)
   .   .   .   .   .   .   .
 (* Preparation of a service message to all nodes and  generation of initial
positions of mobile nodes in given area *)
NET   T4: S4/S3, S5;
TRANS T4: %S5.MTYP := 1;                                  (* Service messge type *)
       %S5.NONB := %NODS;
       %S5.MID  := %NGBR;
       Writeln('SWITCH: Initial node positions:');
       for inod := 1 to %NODS do
       BEGIN
       %XPOS[inod] := UNIFRM (1, %XMIN, %XMAX);
       %yPOS[inod] := UNIFRM (1, %YMIN, %YMAX);
       Writeln('Nd ', inod, ':', %XPOS[inod], ' ', %YPOS[inod]);
       END;
  (* Periodical re-computing of positions of all nodes in the area *)
NET   Y1: S3, S2/S1;
NET   T1: S1/S2;
TIME  T1: %DELAY := %DT;
TRANS T1:                              (* Re-computing after the next time slot *)
       for inod := 1 to %NODS do
       BEGIN
       xi := %XPOS[inod];                  (* Current X-coordinate of next node *)
       yi := %YPOS[inod];                  (* Current Y-coordinate of next node *)
       OK := 0;                                      (* Init flag for X-coordinate *)
       WHILE (OK = 0) do                          (* New X-coodinate of node *)
         BEGIN
         %XNEW := UNIFRM (1, xi - %DX, xi + %DX);
         if (%XNEW > %XMIN) AND (%XNEW < %XMAX)
         then BEGIN %XPOS[inod] := %XNEW; OK := 1; END
         END;
   .   .   .   .   .   .   .
NET  Y1000: s101,s102, …. ,s150/s1000;
     .   .   .   .   .   .   .
(* Outputs to nodes: passing a message to the next node *)
NET   X2000: s2000/s201,s202,s203,…, s250;
CONTR X2000: %OUT := %S2000.NEXT;
     .   .   .   .   .   .   .
LINK SWITCH,NOD50: S150,S100/S250,S200;
SEGEND.
```

Figure 2.2 : The MDL fragment of the switching module.

```
SEGMENT MONOD, TICK = SEC;
ATTRIBUTES
. . . . . .
DATA
. . . . . .
(* Input from SWITCH segment *)
NET   X1: s200/s1, s2;
CONTR X1: IF %S200.MTYP = 1
      THEN %OUT := 1
      ELSE %OUT := 2;                          (* A packet passed to me *)
NET   T1: S1/S4;                    (* Getting info from a service message *)
TRANS T1: %NODS := %S1.NONB;                   (* The number of nodes *)
%SELF := %S1.NEXT;                                        (* My identifier *)
      %NGBR := %S1.MID;              (* How many neighbors to send to? *)
      NET   X4: S4/S5, S6;
CONTR X4: if %SELF = 1               (* Only node 1 may be a source node *)
      then %OUT := 1
      else %OUT := 2;
NET   T6: S6;
(* Periodic transmission of packets by source node *)
NET   Y5: S5, S99/S96;
NET   T5: S96/S97,;
TIME  T5: %DELAY := 2;                                      (* 2 seconds *)
TRANS T5: %S97.MTYP := 2;                  (* A route request message *)
      %S97.SRC := 1;                                  (* Source node Id *)
      %S97.DEST := IUNIFR (1, 2, %NODS);
      %S97.SNDR := 1;
      %S97.TTL  := 7;
        . . . . . .
 (* Checking a received message *)
NET   X2: S2/Q1, S3;
CONTR X2: if %SELF = 1
      then %OUT := 2                 (* Node 1 discards received messages *)
      else %OUT := 1;
NET   T3: S3;
(* Handling  the received message by nodes 2, 3, ..., NODS *)
NET   T2: Q1/S9;
TRANS T2: %S9.TTL := %S9.TTL - 1;
      %S9.HOPS := %S9.HOPS + 1;
NET   X3: S9/S7, S8, S10, S11;
CONTR X3: if (%MSGS[1] = %S9.MID)
      then %OUT := 3                            (* Duplicated message *)
      else if %S9.DEST = %SELF
      then %OUT := 4                             (* Destination node *)
      else if %S9.TTL = 0
      then %OUT := 2                        (* Message with TTL = 0 *)
      else BEGIN                                      (* New message *)
         %MSGS[1] := %S9.MID;                        (* Store its Id *)
         %OUT := 1;                        (* Retransmit the message *)
         END;
. . . . . .
(* Retransmission of the received message *)
NET   T1000: S7/S1000;
TIME  T1000: %DELAY := 0.5;
TRANS T1000: %S1000.SNDR := %SELF;
. . . . . .
NET   Y1000: S999, S1000/S100;
SEGEND.
```

Figure 2.3 : The fragment of the MCL code.

Chapter 3

SYSTEM ASSUMPTIONS AND MOBILITY MODEL

3.1 Assumptions of the System Environment

Through out the work of this thesis, a system of wireless mobile ad hoc network that occupies some restricted area is studied. The network area is assumed to be rectangular, with extreme coordinates $x_{\min}$ and $x_{\max}$ for horizontal axis (X dimension) and $y_{\min}$ and $y_{\max}$ for vertical axis (Y dimension). These coordinate values are system parameters of the network. It is also assumed that, a finite set of mobile nodes that are able to communicate with each other, with the use of bidirectional wireless channels, are populated the network area. The characteristics of these communication links are according to the well known characteristics of radio transmission at very high frequencies. Which means, the transmission radius of each node is limited and even within this limited range, the inter-node communication process is not reliable, due to the various reliability aspects of wireless communications, such as fading effects, interference, presence of obstacles, weather conditions and the state of the node battery.

A further assumption is that, the nodes are moving randomly in the given network area, according to a chosen mobility model. During mobility, the current position of each node i, in the network area, at any moment of time t, is represented with

coordinates $x_i(t)$ and $y_i(t)$. Despite nodes are moving continuously, with random stops for some time interval in real life, the node movement in this model, is represented with small discrete steps. The step duration, time taken for each step, is denoted by τ. Each node *i* changes its position from $(x_i(t), y_i(t))$ at time *t* to position $(x_i(t+\tau), y_i(t+\tau))$ at time $t + \tau$, during this step duration with steps or displacements of $\Delta x_i = x_i(t+\tau) - x_i(t)$ along horizontal axis and $\Delta y_i = y_i(t+\tau) - y_i(t)$ along vertical axis of the network area. The step duration τ is another parameter of the model.

Another system assumption is that, for each node *i*, values of $\Delta x_{\max}$ and $\Delta y_{\max}$ are the upper limits of step sizes Δx_i and Δy_i along two axes. Where $\Delta x_{\max}$ and $\Delta y_{\max}$ are two more parameters of the model. The maximal speeds, in both axes, of each node can be defined with the use of $\Delta x_{\max}$, $\Delta y_{\max}$ and the known step duration τ, according to expressions 3.1 and 3.2.

$$V_{\max}(x) = \Delta x_{\max} / \tau , \tag{3.1}$$

$$V_{\max}(y) = \Delta y_{\max} / \tau . \tag{3.2}$$

An important point to mention is that, the values of actual displacements Δx_i and Δy_i for each node *i*, are uniformly distributed random variables in the range $(0, \Delta x_{\max})$ for horizontal axis and $(0, \Delta y_{\max})$ for vertical axis. During the movement of each node *i*, values of Δx_i and Δy_i are fixed, once chosen from these ranges at the initial node position. As the values of Δx_i and Δy_i are different for different nodes, generally each node is moving with different a speed in the range $(0, V_{\max}(x))$ and $(0, V_{\max}(y))$.

The next assumption is that, the initial node distribution and coordinates for next position of each node, in the given area, is randomly generated. Inherently, the direction of movement of each node is determined by the outcome of these two random processes. This direction can be changed at the end of any step interval, with the specified probability *p*, or always at the network area.

In the case that sufficiently large number of nodes are randomly distributed in the area, the network area with its nodes can be approximated formally as a point Poisson field, which the properties are well known [16]. Where significant characteristics of wireless networks can be indicated with the use of these properties. For example, let the area of region *A* in the network, corresponding to transmission radius *R* is denoted by $S_R(A)$, where the region *A* is simply a circle with radius *R*. If the wireless network has *N* nodes and total area of *S*, then the probability of having *k* nodes in region *A* is shown with expression (3.3),

$$P(n(A)=k)=\frac{(\lambda S_R(A))^k}{k!}=e^{-\lambda S_R(A)}, \tag{3.3}$$

where the intensity of the point Poisson field is equal to $\lambda = N/S$. Expression (3.3) can be very beneficial when determining the probability distribution of distances from any node to the first nearest node, to the second nearest node and so on. Accordingly it can be very useful in the study if routing protocols.

Expression (3.4) can be used to approximate the probability density function of distance from any node to the nearest node in the network and estimate the mean of this density function. In order to see if sufficiently reliable inter-node communication can be achieved with the given number of nodes and the transmission radius.

$$f(r) = \begin{cases} 2\pi\lambda r e^{-\pi\lambda r^2} & for \quad r \geq 0, \\ 0 & for \quad r < 0. \end{cases} \tag{3.4}$$

After stating assumptions of the system environment, the next step is the determination of a mobility model and specification of an inter-node communication scheme to be used in the model. A survey and the chosen mobility model for wireless LANs is given in the rest of this chapter, where the proposed inter-node communication scheme constitutes the topic of the next chapter.

3.2 A Survey of Mobility Models for Wireless LANs and the Chosen Mobility Model

Mobility modeling in wireless networks aims to model single or multiple mobile users. Mobility models can be classified under two main categories, namely synthetic models and models based on actual traces. Considering synthetic models, they can be further classified as independent user or group management models. As the process of modeling is forming an abstraction of a real system, many different abstraction levels are possible, and as the detail level of abstraction increases the number of required assumptions increases as well. So the modeler should be careful to meet the optimum detail level, where the average velocity, stationary node distribution and arrival rate into a given subset are some important properties of mobility models that should be considered well. The model that is considered in this thesis is synthetic, easy to describe and has few parameters, but in the mean time, behaves partially reasonably and analytical results can be derived.

It should be noted that, node mobility is a highly important aspect in wireless ad hoc networks, since an inappropriate representation can result in simulated performance

of the network to be too optimistic or too pessimistic. Nodes can have quite complex movement patterns with varied speeds, directions, stopping rules and behaviors at the network border.

Brownian motion was discovered by R. Brown in 1827. It represents random walk patterns that the first mobility models were based on. Later, Einstein has done a detailed theoretical analysis of the Brownian motion [17] that makes use of this random walk mobility model possible in simulations. Being not realistic and very simple for representing node movements in ad hoc networks, modelers should be careful about simulation parameters as well, since if the interval of the simulation is not carefully chosen, each node will not move away from its initial position and can be appeared as almost immovable [18].

The work in [19] is devoted to modeling and simulation of a cellular radio system and probably the starting point for more realistic mobility models. Where based on the scheme proposed in this work, few variants of mobility models for wireless ad hoc networks are developed. In simulation practice, the random waypoint [20] and the random direction [21] mobility models are the most frequently used variants. The modeler should be fairly accurate, when using random waypoint scheme, as the wrong choice of model parameters can result in a scenario where nodes are almost immovable as in random walk model [18].

The random waypoint mobility model initially distributes the nodes randomly, in the predefined simulation area. The mobility domain of this model is a convex set, where each node selects and moves from waypoint P_i to a new waypoint P_{i+1}, with a uniform distribution of user-specified speeds. Also, the waypoints are uniformly distributed within the, convex set of, simulation area. According to the model, once the

node reaches P_{i+1} , it is stationary for some user defined pause time and select its new waypoint and speed at the end of this pause time and resumes its movement.

However, with the work in [21] an odd behavior of the random waypoint mobility model was investigated. That is, the average number of neighbors of a node periodically fluctuates, as the simulation progresses, with respect to the speeds of the nodes. This periodical increases and decreases are due to the built in characteristics of the mobility model. As the next destination of mobile nodes should be in the simulation area, they are most likely to move in the direction in which there are the most destinations from which to choose. This biases nodes to choose their destinations that are either at the middle or reachable through travelling from the middle of the simulation area. Which results in density waves (that are not realistic), as the nodes converge at the middle of the area and then disperse and then re-converge, etc. The need for constant number of neighbors per node from beginning to the end of simulation, directed us to choose another model, namely the random direction mobility model. With this model, each node selects a direction of travel, which is measured in degrees, instead of a destination within the area, which overcomes the problem of fluctuation of average number of neighbors.

According to the random direction mobility model, each node initially selects a degree from 0 to 359 and through moving in this direction, finds its destination at the network border. The next step is to select a speed which will be constant till the destination is reached and then begin the movement. Once the destination is reached, the node is stationary for the given pause time, and now being at the border of the network, it selects a degree from 0 to 180 to determine its new direction and destination at the network boundary. Then a new speed is selected and the movement is resumed. Fig 3.1

and 3.2 [21] shows the average number of neighbors per node, and proves that the random direction mobility model have more stable node distribution, fewer fluctuations, than the random waypoint model. Being out of the scope of this thesis, detailed discussion of mobility models can be found from [18], [22], [23] and [24].

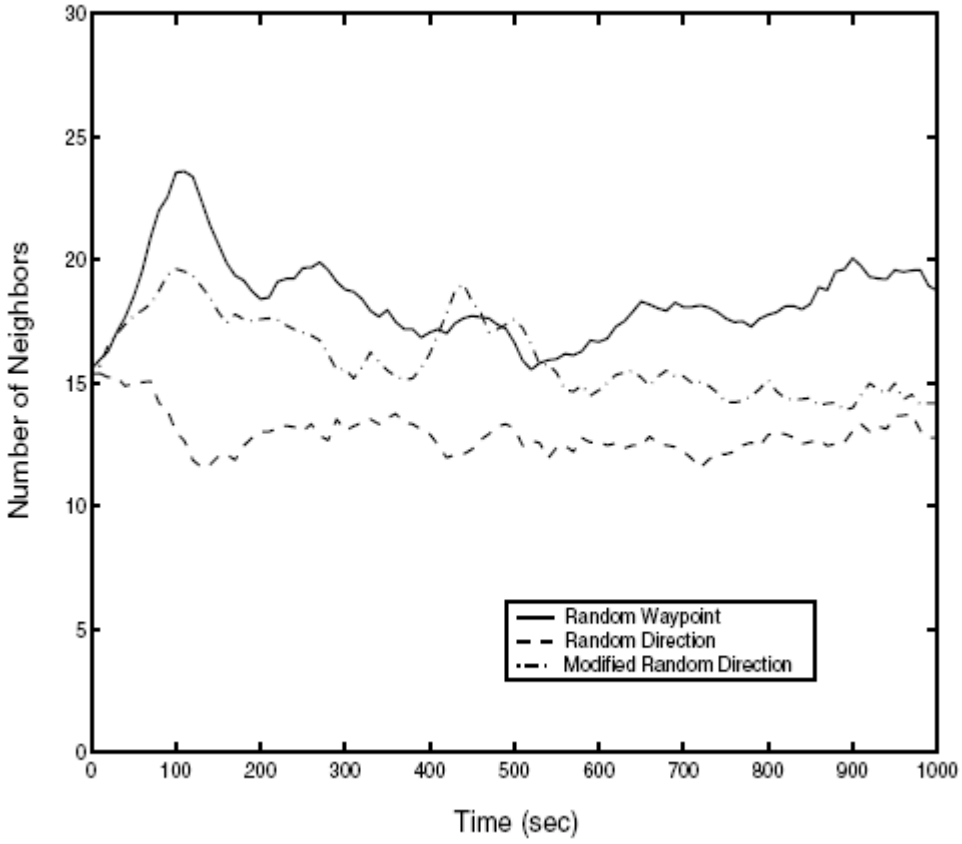

Figure 3.1 : Average number of neighbors per node at 1 m/s mobility for the network consisting of 100 nodes in a 1000 m x 1000 m area [21].

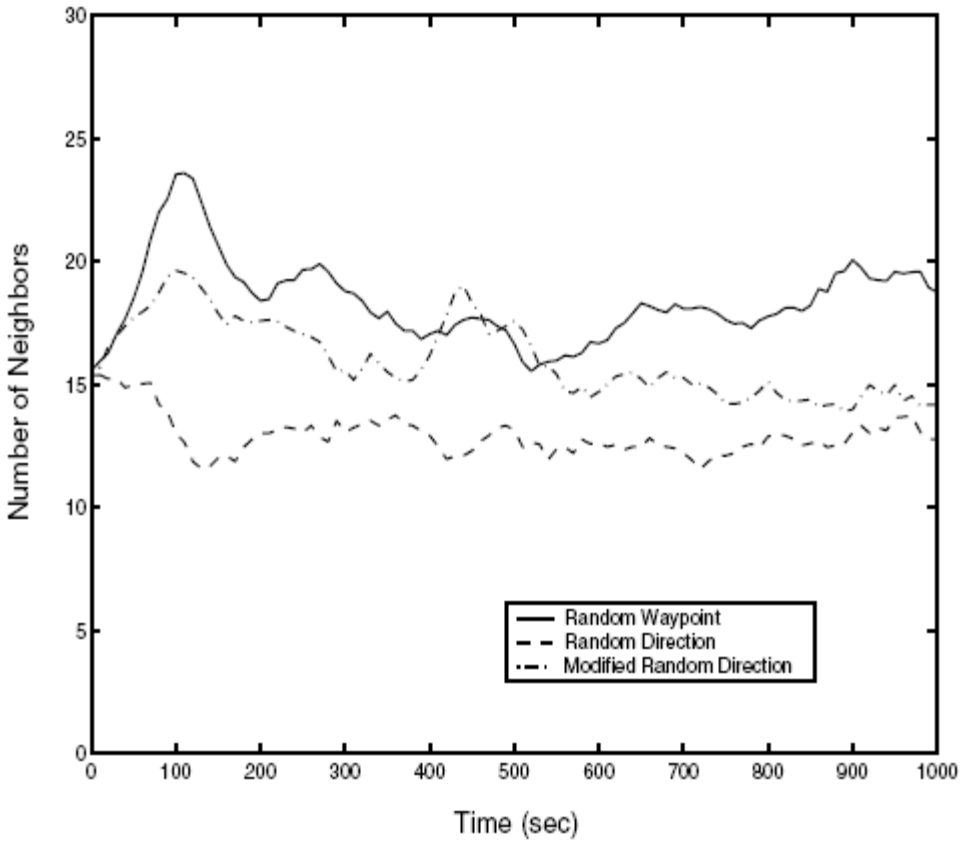

Figure 3.2 : Average number of neighbors per node at 5 m/s mobility for the network consisting of 100 nodes in a 1000 m x 1000 m area [21].

The extended version of random direction mobility model is used, in this thesis, in order to represent motion patterns of nodes. With respect to this model, initial node distribution, determination of the direction and next destination of the movement and the behavior of the node at the area border is same as the original random direction mobility model. However as an extension, each node can change its direction of movement not only at the network border but also, with the specified probability *p*, inside the network area, at the end of any step interval. With the use of *p*, which is a model parameter, different motion patterns of nodes within the network area can be easily represented. The original random direction model can be represented by assigning zero to the value of *p*, where the node can only change its direction of movement at the area border. On

the other hand, the random waypoint or even the pure random walk model can be represented when sufficiently large values are assigned to *p*.

Chapter 4

INTER-NODE COMMUNICATION SCHEME FOR THE MODEL

4.1 Representation of Reliability Aspects of Inter-node Communication

A novel scheme of inter-node communication is proposed and implemented in the developed model of wireless ad hoc network. As stated, the quality of wireless communications at very high frequencies are not guaranteed and, even at short distances, depends on various factors, such as fading effects, interference, the presence of obstacles and weather conditions. Many researchers represent reliability aspects of inter-node communication by specifying some bit error rate or probability of loss of transmitted packets, to simply their model of wireless network. Where generally researchers does not consider that, states of each of the reliability aspects of inter-node communication can vary with respect to the orientation of the sender relative to the receiver. And consequently, the success of a node to receive a packet transmitted by some neighbour node does not depend only on the distance to the transmitter, but also on the orientation with respect to the transmitter. That is to say, in general inter-node communication links are orientation-dependent and should be modelled in this way. Omitting this statement

can result in many inaccurate observations from design to analysis stages of wireless networks, such as the degree of coverage overlap (K-coverage) and number of disjoint paths between any pair of node (K-connectivity).

4.2 The proposed Scheme of Inter-Node Communication

Figure 4.1 illustrates the basic idea of an oriented link between two nodes, namely *A* and *B*, with coordinates ($x(A)$, $y(A)$) and ($x(B)$, $y(B)$) respectively. Assume that node *A* is a sender and node *B* is a potential receiver of a packet transmitted by node *A*. Then the orientation of a communication link between these nodes is represented by

$$\tan(\alpha) = \frac{y(B) - y(A)}{x(B) - x(A)}. \tag{4.1}$$

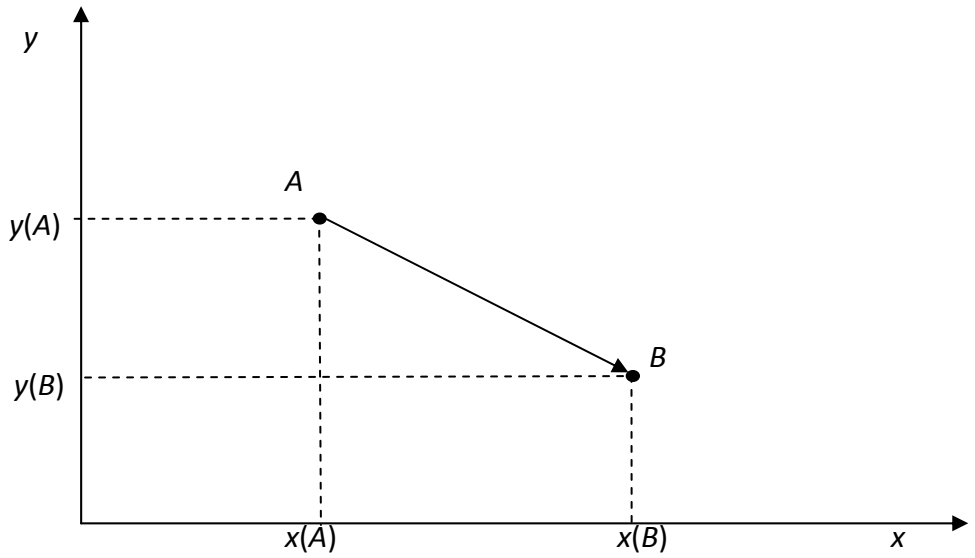

Figure 4.1 : Orientation-dependent communication link between two nodes.

Considering possible orientation from 0 to 360 degrees for a node, the value of tangent can be same for more than one orientation. Therefore to uniquely represent the orientation of a sending node with respect to the receiving node, the signs of difference of $y(B)$ - $y(A)$ and $x(B)$ - $x(A)$ should also be known, and used. For this purpose, each

time when a node transmits a packet, the model provides the coordinates of the transmitting node and the potential receiving node (own coordinates) to each of the potential receivers. This procedure will be explained in more details in the next chapter.

For each node, eight equal sectors are used to group all orientations from possible senders. Accordingly each sector is organized as 45 degrees. Figure 4.2 illustrates eight, 45 degrees, sectors of orientation dependent communication links for a receiving node with coordinates (x_r, y_r).

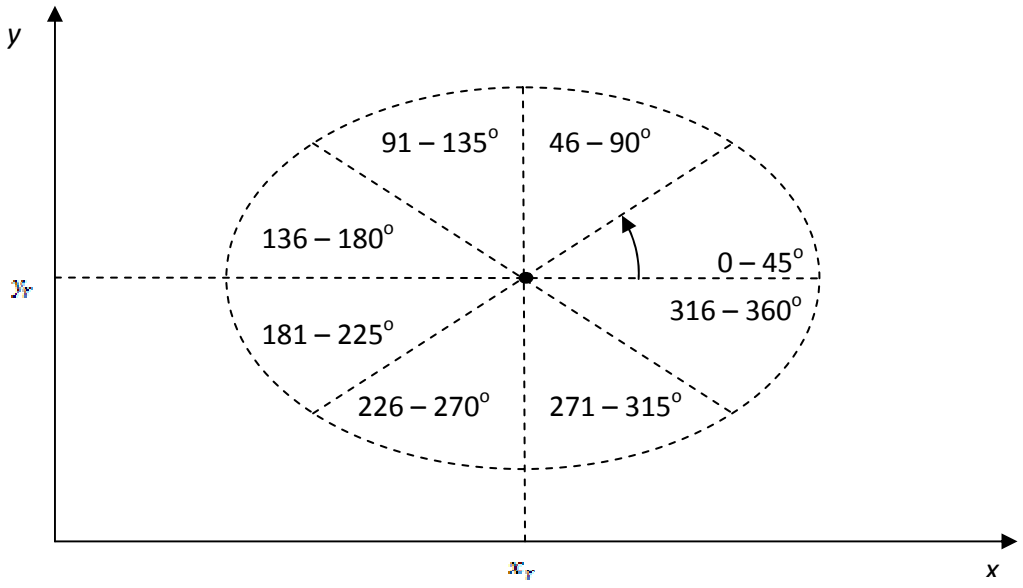

Figure 4.2 : Sectors of orientation-dependent communication links for a receiving node.

In a similar study of Park's [25], a single non-oriented link, which has two alternating states, is assumed. The link can either have ON (active) or OFF (inactive) state, where durations of these states are independent random exponentially distributed variables with mean values $1/\mu$ and $1/\lambda$ respectively. Where μ is the rate of transition from state ON and λ is the rate of transition from state OFF. Under these circumstances,

the behavior of the link can be described as a continuous-time Markov process with two states.

Where a link is characterized by defining, the ratio of time a link is operational, namely the link availability, with the following expression

$$l = \frac{\lambda}{\lambda + \mu}, \tag{4.2}$$

4.3 Generalization of the Scheme

In order to generalize the proposed scheme, a separate link availability is associated to each of the eight oriented links of each node. The current states of each of eight oriented links and the moments of termination of the current state of each link, for each node, are kept in the developed model. Two arrays are used to keep this information.

Every time when a packet is received by a node, initially the link sector which the packet arrived is determined. The current state of the link, corresponding to this sector, is checked. And if the state is ON, then the packet is accepted for subsequent processing. If the state is OFF, the packet is discarded.

As stated in [26], with such a scheme, besides reliability aspects of inter-node communication, the presence of various obstacles, between communicating parties, in various directions during the node movement, in the network area, is represented in an implicit and abstract way.

Based on the inter-node communication, a situation that two communicating nodes are very close to each other, where the communication of these nodes is very reliable, is also taken into account. In this situation, the communication will be treated

independently from the described scheme. The distance that two nodes should be considered as very close to each other is assumed to be a uniformly distributed random variable within the range from zero to a specified small threshold. Figure 4.3 illustrates the area of reliable inter-node communication for a node.

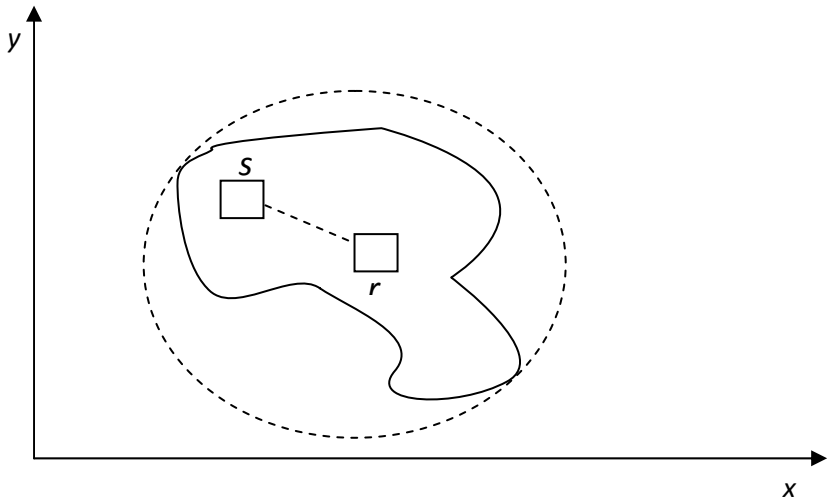

Figure 4.3 : Area of reliable inter-node communication.

The use of multiple oriented links, enables representation of reliability aspects of inter-node communication links in a more general and feasible way, compared to known schemes which uses single non-oriented links and try to model effects of specific patterns and presence of obstacles between network nodes [22]. In addition, the proposed scheme enables faster simulation as it does not require a considerable computation time.

Chapter 5

ORGANIZATION AND COMPONENTS OF THE MODEL

5.1 The Structure of the Model

The proposed model of a mobile wireless ad hoc network is organized as a multi-module system, as shown in Fig. 5.1, that is developed in terms of extended Petri nets. And in order to implement the model simulation system Winsim [13] is used.

As illustrated in Fig. 5.1, the model is composed of two types of modules. The first module implements functionality of mobile nodes, thus called the node module. Which in this case, the number of these modules is equal to the number of mobile nodes in the network.

Switching module is the second type of the modules. This centralized module performs all switching operations of inter-node communication and provides great benefits by drastically reducing the number of connections required for each node. In the case of absence of this module, each node module would require (N - 1) connections to other nodes in the model. Where the total number of connections required will be $N(N - 1)$. Assuming a network of 50 nodes, N = 50, 50(49) = 2450 connections will be required. But with the use of the switching module, only two connections will be

required for each node to communicate with the central switching module. So a network of 50 nodes, $N = 50$, will require 2 x 50 = 100 connections only, see Fig. 5.1.

In addition, random movement of nodes in the network area, determination of nodes, for each transmitted packet, that are potentially reachable from a transmitting node with given transmission radius, and forwarding of the transmitted packets to these potential receivers, for subsequent processing according to the scheme of inter-node oriented links are handled by the switching module.

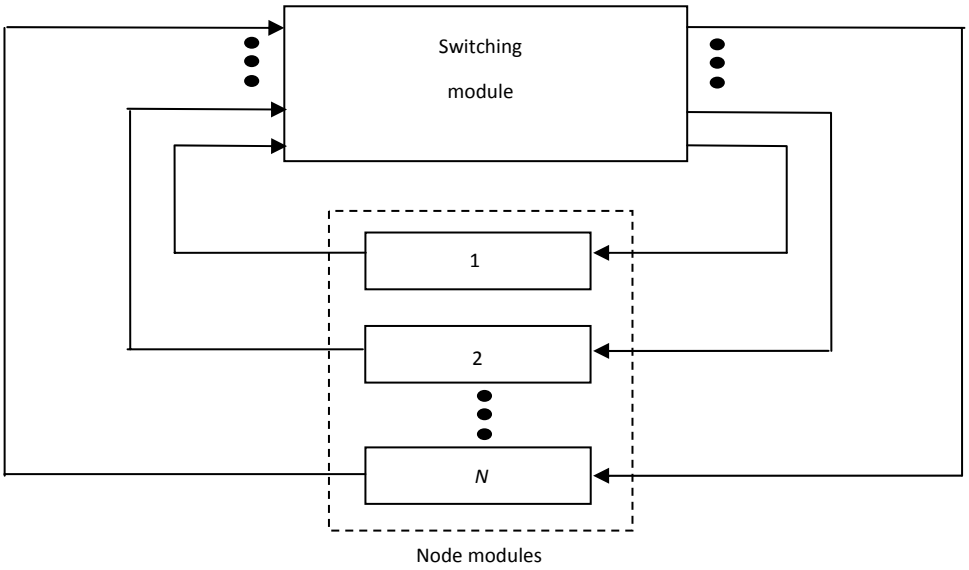

Figure 5.1 : The structure of the model.

A segment that is implemented in terms of extended Petri nets is used to represent each of the two types of modules in the model. That is, the model is composed of two types of segments. The first type of the segments is the node segment. One copy of this segment is needed for each node in the model, as a node segment is able to perform functionality if a single node only. Consequently, in order to implement multiple nodes, any desired number of identical copies of a single segment can be automatically generated by the simulation system.

Switching segment is the second type of the segments. There is only one copy of the switching segment for the entire model.

5.2 Representation of Modules in Terms of Extended Petri Nets

5.2.1 Petri Net Scheme of the Switching Module

The Petri-net scheme of the corresponding module is shown in Fig. 5.2. Accordingly to its functionality, specification of the initial random distribution of positions of nodes in the network area, periodically re-computation of node positions to imitate mobility of nodes, determination of potentially reachable nodes, for each transmitted packet, according to the transmission radius, and forwarding of these packets to reachable nodes are performed by the switching module. Note that a forwarded packet can be discarded by the receiving node, according to the current state of the inter-node communication link with respect to the transmitting node, even if it is considered as potentially reachable by the switching module.

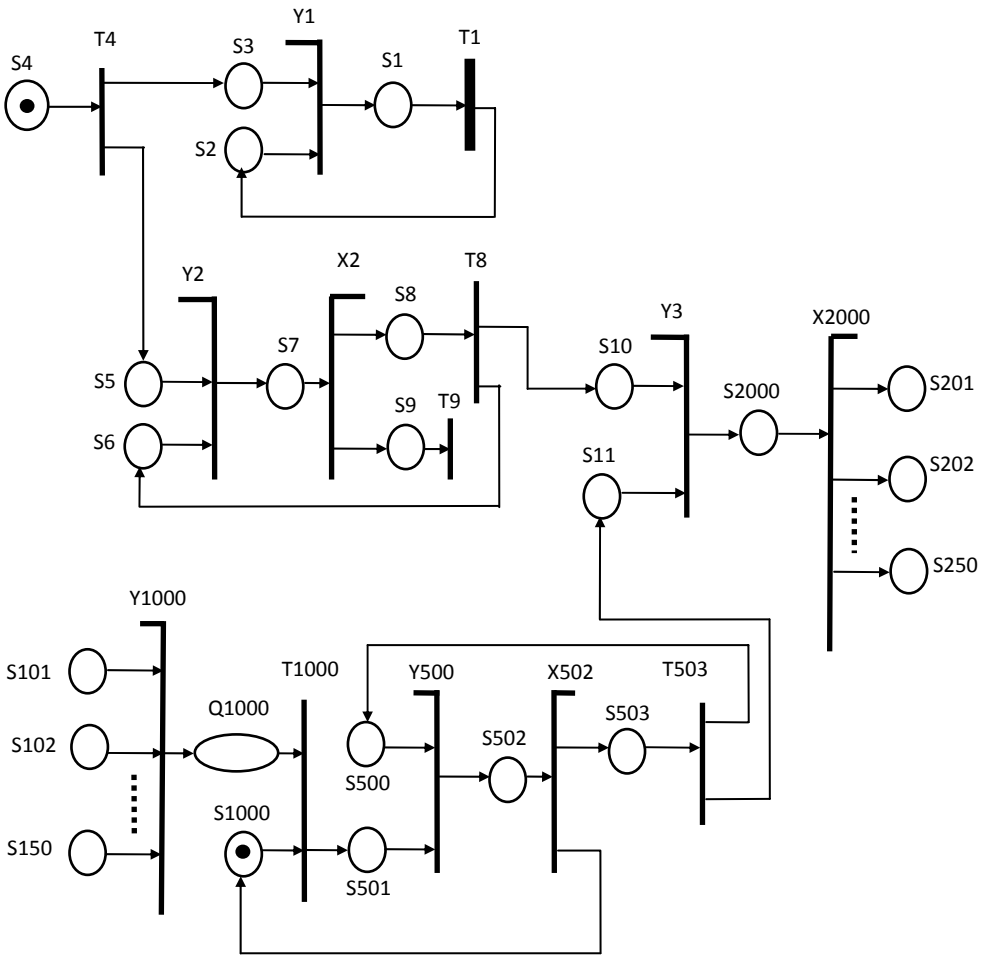

Figure 5.2 : Petri net scheme of the switching module.

The schema illustrated in Fig. 5.2 indicates that there are 50 nodes in the network. Accordingly, places {S101, S102, …, S150} represents input places of the switching module that are used to establish connections from every node module to the switching module, for processing and forwarding of transmitted packets and places {S201, S202, …, S250} are output places of the switching module. The output places are used to establish connections from the switching module to every node in the model, for transmission of packets to potentially reachable nodes.

The elementary net with transition T4 is responsible for preparation of an initialization information to inform each node with the number of nodes in the network

area, and computation of the initial distribution and next positions of nodes, which determines the direction of movement of each node. Coordinates of these initial and next positions of nodes are stored in arrays located in the switching segment.

The infinite loop with places S1, S2 and S3 and transitions Y1 and T1 periodically re-compute positions of all mobile nodes in the area. The probability to change the direction of node movement and whether any of the boundaries of the area is reached is checked, to determine if the direction of movement needs to be changed. The updated coordinates of new positions of nodes are stored in the aforementioned arrays.

The second loop with transitions Y2, X2, T8 and T9 with incident places, iterates for fixed number of times and generates an initialization message for each node module. This initialization message includes the total number of nodes in the network and the numeric identifiers assigned to respective nodes. The multiplexing transition Y3 is used to pass the initialization messages to corresponding nodes, via transition X2000 and its output places. This (second) loop is performed at the very beginning of the simulation for only once.

Elementary nets associated with transitions T100, Y500, X502 and T503 are used to perform switching operations. Each packet transmitted by some node enters the queue Q1000, and consequently transition T100 handles the request from the transmitting nodes, to pass a packet to neighbour nodes, by determining the ID, X-coordinate and Y-coordinate of requesting node as well as potentially reachable neighbours of the requesting node, according to the transmission radius. Then the loop with transitions Y500, X502 and T503 is used to pass the corresponding packet to all reachable neighbours.

5.2.2 Petri Net Scheme of the Node Module

The Petri-net scheme of the node segment is shown in Fig. 5.3. Places S200 and S100 are input and output places of the node segment that are used to communicate with the switching segment, and therefore with all other node segments. The elementary net with transition X1 is responsible for separation of data packets, transmitted by other node modules, from initialization messages that are transmitted by the switching segment. Initialization messages are directed to place S1 and corresponding initialization information, such as the number of nodes in the network and the unique identifier of the node, is registered at transition T1. Furthermore, initializations of states of each of the eight oriented links with durations of each of these states are performed by transition T1.

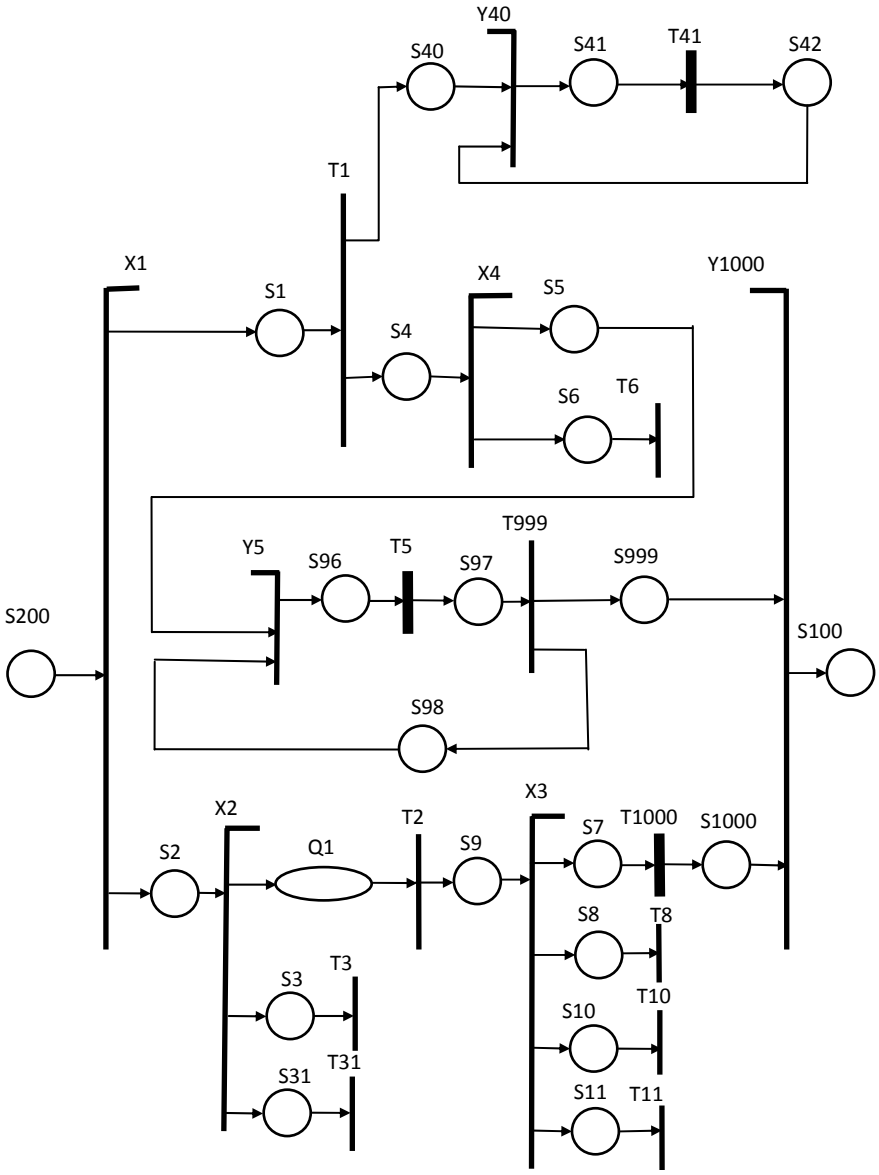

Figure 5.3 : Petri net scheme of the node module.

After this point, two concurrent processes start running. The first process is implemented with transitions Y40 and T41 as a loop. The states of oriented links of the node are computed periodically by this loop, according to the proposed scheme of orientation-dependent inter-node communication links. Where two arrays located in each node segment are used to store the state information. The second loop is implemented with transitions Y5, T5 and T999. It generates data packets periodically

and passes them to the switching segment via transition Y100 and output place S100. With the current model, there is only one node that serves as the originator for all the transmitted packets, this is still enough to investigate behaviour of performance metrics of the modelled network. For this purpose, transition X4 is used to determine if the corresponding node is the source (originator) node, if its node identifier is equal to 1, and then lets the node to iterate the second loop. Furthermore, transition T5 assigns a destination address to each generated packet that is different than the source node's identifier. The time associated with transition T5 introduces the random inter-node transfer time. Besides a destination address, a fixed time-to-live (TTL) value and a numeric identifier of the packet is assigned to each generated packet.

Place S2 is the input place for data packets that are passed from the switching module. The received data packets are handled by transition X2. Its control procedure analyzes the data packets and takes one of the three following decisions. First, it is checked, if the node is the originator of packets, if it is, then the packet is always discarded and absorbed by transition T3. Second, it is checked, if the packet is received from a very close node, where it is always accepted, or from the sector with respect to the last forwarding node that the current state of the link is ON. In both cases, the packet is accepted and enters the queue place Q1 for subsequent processing. In the third case, if the received packet is from the sector that current state of the link is OFF, the packet is discarded and absorbed by transition T31.

Then the subsequent processing of each accepted packet is as follow; initially the value of TTL is decremented and the number of passed hops for the received packet is incremented, then it is checked whether the received packet is duplicated or a new one. These three operations are performed by transition T2.

Finally the decision related to the received packet is made by the control procedure associated with transition X3. The decision depends on the value of the packet's TTL field, destination address and the value of the flag that shows if the packet is duplicated one. If the TTL value of the packet is zero or the flag shows that it is duplicated, the packet is discarded and absorbed by transition T8 or T10 respectively. If the destination address of the packet is the node's identifier, then the packet is accepted by this node, via transition T11. And lastly, if none of the above conditions are valid, the packet is passed to the switching module, via transition T1000 and Y1000, for further transmission. For each of these four conditions, the related statistical information is collected by the node.

Source texts of the switching and node modules written in Model Description Language (MDL) of simulation system Winsim can be referred for the complete understanding of the model.

Chapter 6

SIMULATION SETUP AND RESULTS OF SIMULATION

6.1 Simulation Setup and Performance Metrics

Simulation system Winsim [13] was the tool used to organize and conduct simulation experiments, according to the following setup.

The network area is assumed to be rectangular (square) of 500 x 500 m^2, which is a realistic scale for small or medium sized ad hoc networks, and 50 mobile nodes are used to populate the area. This makes the network area sparsely populated. Since initial positions of nodes are random, with uniform probability distribution along both coordinates (vertical and horizontal), and different for different simulation runs, the network area with its nodes can be approximated as a point Poisson field [16].

The packets are generated and send periodically, with the period of 500 ms by only one source node, where all the remaining nodes behaves as intermediate nodes, that retransmits packets, or serves as destinations for packets. A unique number, time-to-live value of 7, and a random destination node identifier, which has integer uniform probability distribution, are assigned by the source node to each generated packet.

In order to have sufficiently stable statistical results of simulation at least 2000 packets should and will be generated by the source node, and since the periodic interval of generation and sending of the packets is 500 ms, the simulation interval is set to be

1001000 ms = (2000 packets) 500 ms/packet + 1000 ms, where 1000ms is a small time interval to remove tokens from the model.

According to the scheme explained in Chapter 4, the inter-node communication is considered as very reliable, for nodes that are very close to each other. For this reason, in the model, the distance to very close nodes is assumed to be a random variable which has lower bound equal to zero and upper bound being uniformly distributed from 5 to 10 meters.

One more parameter of the inter-node communication scheme is the interval that the states of oriented inter-node communication links are checked. The interval is same for all simulation experiments and set at 2000 ms, where at the end of this interval the state of each link can change.

Two series of experiments were conducted in simulation. In the first series, the transmission radius was the varied variable, in the range (30, 180) m, with four values of link availability l = 0.05, 0.1, 0.3 and 0.5 and two node movement speeds up to V = 3.6 and 14.4 km/h, as parameter. Thus the chosen performance metrics were studied with various transmission distances, link availabilities and node movement speeds.

In the second series of simulation experiments, the link availability was the varied variable, with values l = 0.05, 0.1, 0.15, 0.2 and 0.25, where transmission radius was set at 300m and the maximal node speed was 3.6 km/h. In this series of experiments, the dependence of performance metrics on link availability was examined, where the average number of hops was especially interested for comparison with similar experiments described in [25].

The value of TTL was set at 7 for each generated packet and a variant of the mobility model that the nodes change direction of their movement randomly only at the border of the network area is assumed, for both series of experiments.

A number of performance metrics are used, by researchers, after conducting experiments, in investigation of wireless ad hoc networks. Since the simulation results that are in raw form are hard to understand and in vast amount. Most popular performance metrics used in simulations are the delivery ratio and the average number of hops per delivered packet. Both of these performance metrics reflects very important characteristics of behaviour of wireless ad hoc networks. Delivery ratio characterizes the effectiveness of the network in delivering packets from source nodes to destination nodes. And the efficiency of forwarding of packets from a source to a destination, through intermediate nodes acting as routers, is represented by the average number of hops. Once can realize from the definitions that, both performance metrics highly depend on the node density of the network area, implemented routing scheme, node mobility patterns and characteristics of inter-node communication links.

One more characteristic of the network behaviour that we call relative traffic in this thesis is very important and should be investigated as well, since each packet transmitted by the source node, will be generally retransmitted by a number of intermediate nodes, working as routers, before received by the destination node. The number of times that each packet will be retransmitted by other nodes is shown by the relative traffic. Where some of these retransmissions, depending on the routing scheme, can produce useless/duplicated packets that can reduce the network security, be expensive in terms of node battery life, and results in overloading of the network. Therefore, having the relative traffic as low as possible is desirable.

Assuming that there is only one originator node in the network, three performance metrics mentioned above, can be formally defined as follows.

The first performance metric, delivery ratio of packets, is defined with the expression

$$n_d = \frac{N_d}{N_s}, \tag{6.1}$$

where N_s is the number of packets transmitted by the source node and N_d is the number of packets delivered to destination nodes. In the developed simulation model, the number of firings of transition T999 in the Petri net scheme of a node module (source node) represents the N_s, see Fig. 5.3, and

$$N_d = \sum_{i=1}^{N} T11(i), \tag{6.2}$$

where T11(i) is the number of firings of transition T11 in the scheme of node i and N is the number of nodes. Accordingly, the value of $0 \leq n_d \leq 1$, with the ideal (maximal) value being equal to one, $n_d = 1$.

The formal definition of the second performance metric, number of hops per delivered packet, is as follows. Let the number of nodes that at least one packet is delivered be $L <= N$. Assume, without the loss of generality, that the destination nodes have numbers 1, 2, …, L and the number of packets delivered to node i after h_{ij} hops be denoted by m_{ij}. Then, the average number of hops per delivered packet, for each destination node i, is

$$h_i = \frac{\sum_{j=1}^{k_i} m_{ij} h_{ij}}{\sum_{j=1}^{k_i} m_{ij}}, \tag{6.3}$$

where k_i is the number of packets having the same hop counter at node i, $i = 1, 2, \ldots, L$. The developed model computes these values for each node $i \in \{1, 2, \ldots, L\}$. The overall average number of hops per delivered packet, based on these values, is

$$h = \frac{\sum_{i=1}^{L} h_i m_i}{\sum_{i=1}^{L} m_i}, \tag{6.4}$$

where

$$m_i = \sum_{j=1}^{k_j} m_{ij}, \tag{6.5}$$

is the number of packets delivered to node i.

The third performance metric, relative traffic, is estimated with the use of expression

$$n_f = \frac{N_f}{N_s}, \tag{6.6}$$

where N_f is the number of packets transmitted by all network nodes. Packets transmitted from the source node (N_s) and all other nodes are included in this number. Generally, $n_f \geq 1$ with ideal (minimal) value being equal to one, $n_f = 1$.

The number of firings of transition Y1000 in the scheme of the switching module of the model, see Fig. 5.2, represents N_f.

Note that generalization of the expressions of three performance metrics for an arbitrary number of source nodes can be easily done.

6.2 Simulation Results

In consequence of simulation experiments, a vast amount of raw simulation data is obtained from the simulation system Winsim. Since, in order to find the best

estimation of each of performance measures and error of these estimations four simulation runs were conducted for each of six transmission radius, four link availability and two node movement speed. As a result, 192 simulation runs was conducted. And for comparison purposes, with similar experiments [25] 30 more simulations were run, which sums up to total of 222 simulation runs and analysis of more than 22200 values out of 222 files. A file of raw simulation data of one simulation runs, corresponding to transmission radius of 180 meters and link availability of 0.5 with maximal node speed up to 3.6 km/h, is available in Appendix D.

The main simulation results are presented in forms of a number of tables, Tables 6.1 – 6.10, and graphs, in Figs. 6.1 – 6.7. Tables 6.1 – 6.4 contain simulation results for the proposed network with maximal node speed up to V = 3.6 km/h and link availability l = 0.05, 0.1, 0.3 and 0.5 respectively. The maximal node speed was set to V = 14.4 km/h with four different link availabilities at Tables 6.5 – 6.8. Each of these eight tables shows the values of performance metrics obtained, for six different transmission radiuses, in four simulation runs.

Table 6.1 : Simulation results of the delivery ratio and relative traffic for link availability $l = 0.05$ and maximal node speed $V = 3.6$ km/h.

Maximum distance of transmission of a node, m	Simulation run	N_d	N_f	n_d	n_f
30	1	1	2034	0.0005	1.017
	2	3	2116	0.0015	1.058
	3	2	2028	0.001	1.014
	4	1	2043	0.0005	1.0215
60	1	3	2135	0.0015	1.0675
	2	13	2639	0.0065	1.3195
	3	3	2183	0.0015	1.0915
	4	13	2450	0.0065	1.225
90	1	14	2847	0.007	1.4235
	2	19	2835	0.0095	1.4175
	3	21	3014	0.0105	1.507
	4	13	2598	0.0065	1.299
120	1	35	3626	0.0175	1.813
	2	25	3275	0.0125	1.6375
	3	27	2994	0.0135	1.497
	4	26	3257	0.013	1.6285
150	1	54	4794	0.027	2.397
	2	50	4584	0.025	2.292
	3	50	4300	0.025	2.15
	4	52	4353	0.026	2.1765
180	1	73	6132	0.0365	3.066
	2	97	6392	0.0485	3.196
	3	84	6215	0.042	3.1075
	4	86	6545	0.043	3.2725

Table 6.2 : Simulation results of the delivery ratio and relative traffic for link availability $l = 0.1$ and maximal node speed $V = 3.6$ km/h.

Maximum distance of transmission of a node, m	Simulation run	N_d	N_f	n_d	n_f
30	1	1	2048	0.0005	1.024
	2	4	2071	0.002	1.0355
	3	1	2057	0.0005	1.0285
	4	4	2089	0.002	1.0445
60	1	7	2334	0.0035	1.167
	2	13	2510	0.0065	1.255
	3	12	2586	0.006	1.293
	4	13	2626	0.0065	1.313
90	1	33	3405	0.0165	1.7025
	2	13	2595	0.0065	1.2975
	3	33	3315	0.0165	1.6575
	4	22	3562	0.011	1.781
120	1	53	4495	0.0265	2.2475
	2	48	4380	0.024	2.19
	3	60	4728	0.03	2.364
	4	64	4342	0.032	2.171
150	1	164	9618	0.082	4.809
	2	101	6215	0.0505	3.1075
	3	161	9731	0.0805	4.8655
	4	128	8534	0.064	4.267
180	1	293	16267	0.1465	8.1335
	2	235	12959	0.1175	6.4795
	3	178	10063	0.089	5.0315
	4	319	15474	0.1595	7.737

Table 6.3 : Simulation results of the delivery ratio and relative traffic for link availability $l = 0.3$ and maximal node speed $V = 3.6$ km/h.

Maximum distance of transmission of a node, m	Simulation run	N_d	N_f	n_d	n_f
30	1	5	2230	0.0025	1.115
	2	8	2449	0.004	1.2245
	3	6	2239	0.003	1.1195
	4	16	2802	0.008	1.401
60	1	14	2675	0.007	1.3375
	2	36	3373	0.018	1.6865
	3	46	4759	0.023	2.3795
	4	42	4040	0.021	2.02
90	1	180	10916	0.09	5.458
	2	85	5846	0.0425	2.923
	3	147	9718	0.0735	4.859
	4	179	11273	0.0895	5.6365
120	1	509	25113	0.2545	12.5565
	2	328	15194	0.164	7.597
	3	330	16122	0.165	8.061
	4	412	20161	0.206	10.0805
150	1	1072	47058	0.536	23.529
	2	1032	45963	0.516	22.9815
	3	1042	45790	0.521	22.895
	4	1066	50390	0.533	25.195
180	1	1538	71542	0.769	35.771
	2	1617	76758	0.8085	38.379
	3	1470	70338	0.735	35.169
	4	1632	73864	0.816	36.932

Table 6.4 : Simulation results of the delivery ratio and relative traffic for link availability $l = 0.5$ and maximal node speed $V = 3.6$ km/h.

Maximum distance of transmission of a node, m	Simulation run	N_d	N_f	n_d	n_f
30	1	2	2238	0.001	1.119
	2	9	2619	0.0045	1.3095
	3	30	3061	0.015	1.5305
	4	7	2282	0.0035	1.141
60	1	52	4088	0.026	2.044
	2	65	5184	0.0325	2.592
	3	127	7594	0.0635	3.797
	4	80	5746	0.04	2.873
90	1	231	13363	0.1155	6.6815
	2	322	15188	0.161	7.594
	3	363	17805	0.1815	8.9025
	4	369	17822	0.1845	8.911
120	1	1150	52479	0.575	26.2395
	2	1272	57891	0.636	28.9455
	3	1082	45727	0.541	22.8635
	4	1150	51884	0.575	25.942
150	1	1837	84600	0.9185	42.3
	2	1632	71270	0.816	35.635
	3	1678	74120	0.839	37.06
	4	1699	77273	0.8495	38.6365
180	1	1915	92789	0.9575	46.3945
	2	1924	91904	0.962	45.952
	3	1783	83392	0.8915	41.696
	4	1911	91671	0.9555	45.8355

Table 6.5 : Simulation results of the delivery ratio and relative traffic for link availability $l = 0.05$ and maximal node speed $V = 14.4$ km/h

Maximum distance of transmission of a node, m	Simulation run	N_d	N_f	n_d	n_f
30	1	3	2055	0.0015	1.0275
	2	2	2090	0.001	1.045
	3	1	2048	0.0005	1.024
	4	0	2058	0	1.029
60	1	6	2433	0.003	1.2165
	2	5	2274	0.0025	1.137
	3	5	2215	0.0025	1.1075
	4	2	2273	0.001	1.1365
90	1	12	2506	0.006	1.253
	2	10	2570	0.005	1.285
	3	5	2399	0.0025	1.1995
	4	19	2836	0.0095	1.418
120	1	32	3395	0.016	1.6975
	2	42	3792	0.021	1.896
	3	23	3328	0.0115	1.664
	4	31	3444	0.0155	1.722
150	1	49	4581	0.0245	2.2905
	2	36	3807	0.018	1.9035
	3	53	4433	0.0265	2.2165
	4	47	4285	0.0235	2.1425
180	1	77	5587	0.0385	2.7935
	2	82	5771	0.041	2.8855
	3	99	5969	0.0495	2.9845
	4	78	5991	0.039	2.9955

Table 6.6 : Simulation results of the delivery ratio and relative traffic for link availability $l = 0.1$ and maximal node speed $V = 14.4$ km/h.

Maximum distance of transmission of a node, m	Simulation run	N_d	N_f	n_d	n_f
30	1	4	2165	0.002	1.0825
	2	4	2204	0.002	1.102
	3	0	2051	0	1.0255
	4	6	2111	0.003	1.0555
60	1	3	2351	0.0015	1.1755
	2	14	2421	0.007	1.2105
	3	8	2528	0.004	1.264
	4	9	2487	0.0045	1.2435
90	1	40	3465	0.02	1.7325
	2	30	3577	0.015	1.7885
	3	19	3132	0.0095	1.566
	4	39	3466	0.0195	1.733
120	1	76	5328	0.038	2.664
	2	43	4530	0.0215	2.265
	3	61	4419	0.0305	2.2095
	4	56	4652	0.028	2.326
150	1	124	7684	0.062	3.842
	2	177	7322	0.0885	3.661
	3	123	7231	0.0615	3.6155
	4	127	7806	0.0635	3.903
180	1	307	14262	0.1535	7.131
	2	283	14262	0.1415	7.131
	3	240	13201	0.12	6.6005
	4	286	14717	0.143	7.3585

Table 6.7 : Simulation results of the delivery ratio and relative traffic for link availability $l = 0.3$ and maximal node speed $V = 14.4$ km/h.

Maximum distance of transmission of a node, m	Simulation run	N_d	N_f	n_d	n_f
30	1	7	2557	0.0035	1.2785
	2	8	2314	0.004	1.157
	3	7	2227	0.0035	1.1135
	4	6	2290	0.003	1.145
60	1	40	3530	0.02	1.765
	2	44	3388	0.022	1.694
	3	65	4639	0.0325	2.3195
	4	27	3462	0.0135	1.731
90	1	204	10564	0.102	5.282
	2	181	9942	0.0905	4.971
	3	96	6319	0.048	3.1595
	4	153	8988	0.0765	4.494
120	1	407	20018	0.2035	10.009
	2	592	28623	0.296	14.3115
	3	401	19235	0.2005	9.6175
	4	368	18547	0.184	9.2735
150	1	996	46199	0.498	23.0995
	2	857	40283	0.4285	20.1415
	3	1039	49242	0.5195	24.621
	4	1019	45734	0.5095	22.867
180	1	1520	71520	0.76	35.76
	2	1588	73815	0.794	36.9075
	3	1312	57203	0.656	28.6015
	4	1381	62614	0.6905	31.307

Table 6.8 : Simulation results of the delivery ratio and relative traffic for link availability $l = 0.5$ and maximal node speed $V = 14.4$ km/h.

Maximum distance of transmission of a node, m	Simulation run	N_d	N_f	n_d	n_f
30	1	23	2829	0.0115	1.4145
	2	13	2544	0.0065	1.272
	3	11	2525	0.0055	1.2625
	4	10	2432	0.005	1.216
60	1	52	4944	0.026	2.472
	2	36	4603	0.018	2.3015
	3	79	5360	0.0395	2.68
	4	58	5020	0.029	2.51
90	1	455	21005	0.2275	10.5025
	2	282	15415	0.141	7.7075
	3	208	12172	0.104	6.086
	4	239	13483	0.1195	6.7415
120	1	1063	49606	0.5315	24.803
	2	1070	46307	0.535	23.1535
	3	1006	44881	0.503	22.4405
	4	1086	48491	0.543	24.2455
150	1	1709	78851	0.8545	39.4255
	2	1667	75351	0.8335	37.6755
	3	1790	80348	0.895	40.174
	4	1674	76062	0.837	38.031
180	1	1884	90986	0.942	45.493
	2	1887	91016	0.9435	45.508
	3	1889	89490	0.9445	44.745
	4	1910	92027	0.955	46.0135

The values of average number of hops are investigated, in four simulation runs, with maximal node speed up to $V = 3.6$ km/h in Table 6.9 and maximal node speed up to $V = 14.4$ km/h in Table 6.10.

Table 6.9 : Simulation results of the average number of hops for maximal node speed V = 3.6 km/h.

Maximum distance of transmission of a node, m	Simulation run	Link availability	
		$l = 0.05$	$l = 0.5$
30	1	1.391304	1.5
	2	1	1.333333
	3	1	1.266667
	4	1	1
60	1	2.333333	1.807692
	2	1.076923	2.076923
	3	1.333333	1.448819
	4	1.153846	1.9625
90	1	1.785714	2.623377
	2	1.315789	2.931677
	3	2	3.553719
	4	1.384615	3.279133
120	1	2.542857	3.465217
	2	1.64	3.925314
	3	1.666667	3.719963
	4	1.730769	3.753913
150	1	1.962264	3.444747
	2	2.46	3.976716
	3	2.04	4.100119
	4	1.942308	3.562684
180	1	2.054795	2.890339
	2	2.175258	3.178274
	3	2.488095	3.48009
	4	1.953488	3.202512

Table 6.10 : Simulation results of the average number of hops for maximal node speed V = 14.4 km/h.

Maximum distance of transmission of a node, m	Simulation run	Link availability	
		l = 0.05	l = 0.5
30	1	1	1.391304
	2	1	1.230769
	3	1	1.090909
	4	0	1.2
60	1	1.166667	1.769231
	2	1	1.75
	3	1	1.772152
	4	1	1.448276
90	1	2.416667	3.065934
	2	1.6	2.783688
	3	1	2.725962
	4	2.210526	2.958159
120	1	2.15625	3.75635
	2	1.904762	3.847664
	3	2.391304	3.823062
	4	2.064516	3.773481
150	1	2.346939	3.557051
	2	2.111111	3.627475
	3	2.339623	3.698883
	4	2.531915	3.758064
180	1	2.207792	3.005839
	2	2.378049	3.131426
	3	2.242424	3.182636
	4	2.064103	2.957068

Figs. 6.1 – 6.7 represent simulation results of the proposed wireless ad hoc network with various transmission radiuses, link availabilities and maximal node speeds in graphical form. The maximal node speed was set at 3.6 km/h in Figs. 6.1 – 6.3 and 14.4 km/h in Figs. 6.4 – 6.6. Fig 6.7 demonstrates the dependence of the average number of hops on link availability, with maximal node speed set at V = 3.6 km/h.

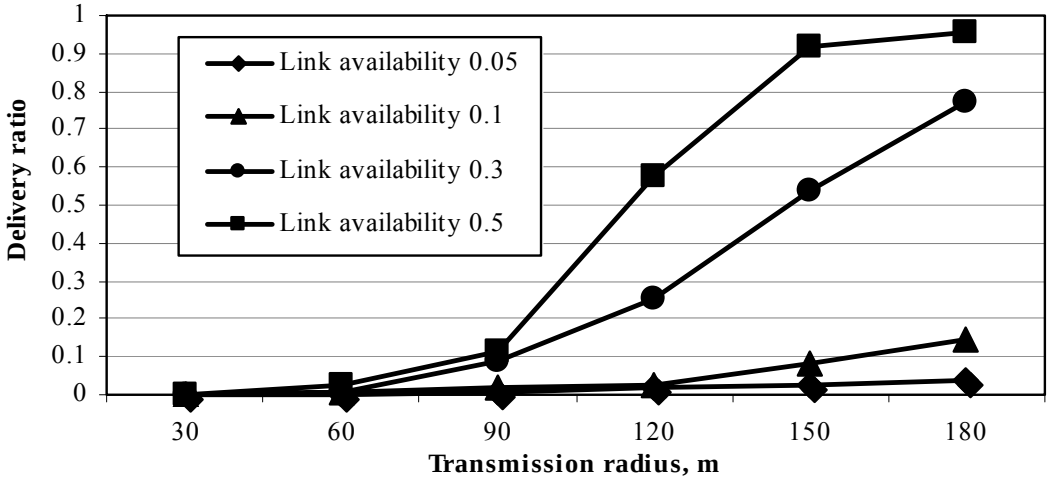

Figure 6.1 : Delivery ratio, n_d , versus transmission radius with maximal node speed 3.6 km/h.

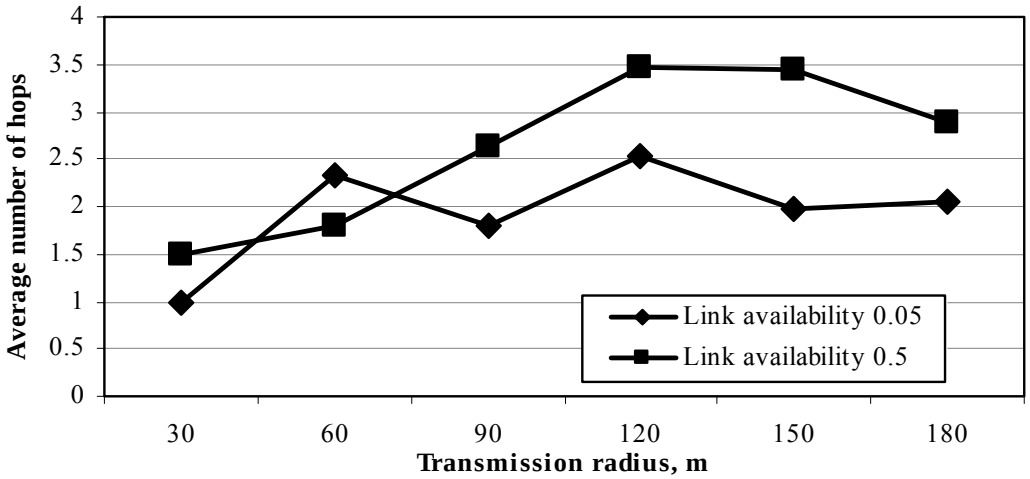

Figure 6.2 : Average number of hops, *h*, versus transmission radius with maximal node speed 3.6 km/h.

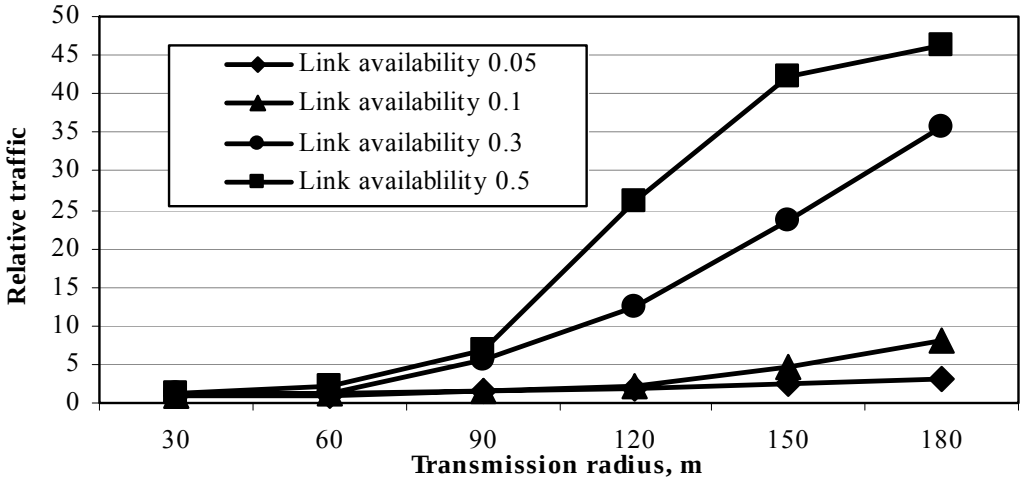

Figure 6.3 : Relative traffic, n_f , versus transmission radius with maximal node speed 3.6 km/h.

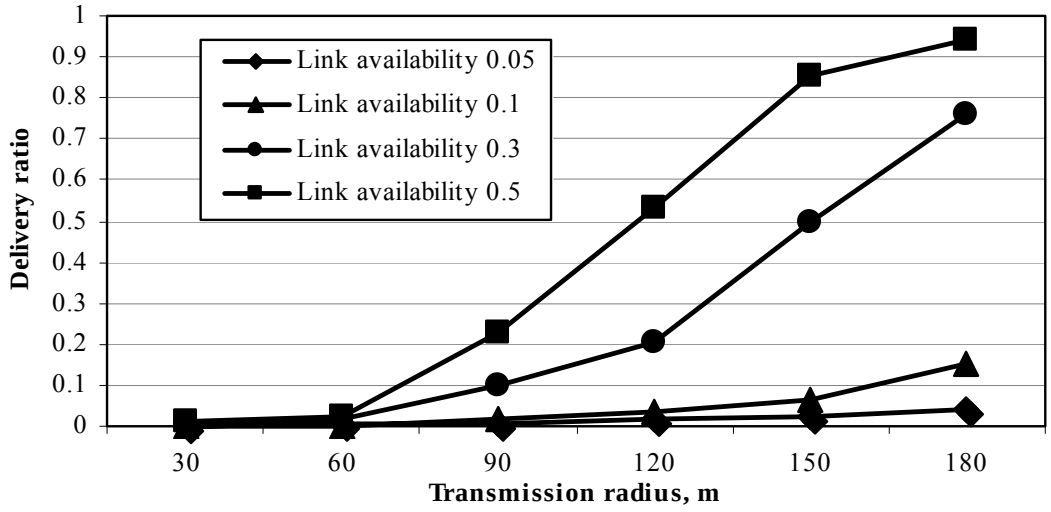

Figure 6.4 : Delivery ratio, n_d , versus transmission radius with maximal node speed 14.4 km/h.

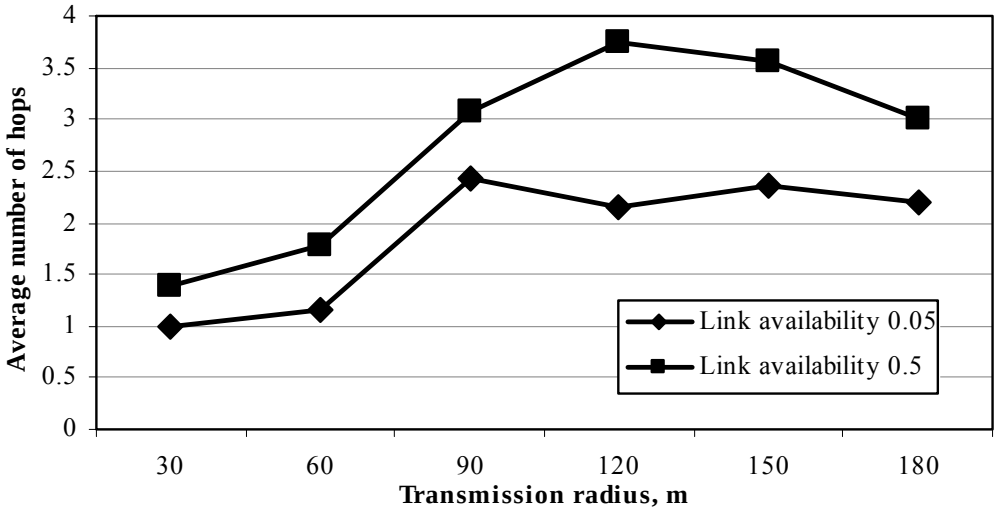

Figure 6.5 : Average number of hops, *h*, versus transmission radius with maximal node speed 14.4 km/h.

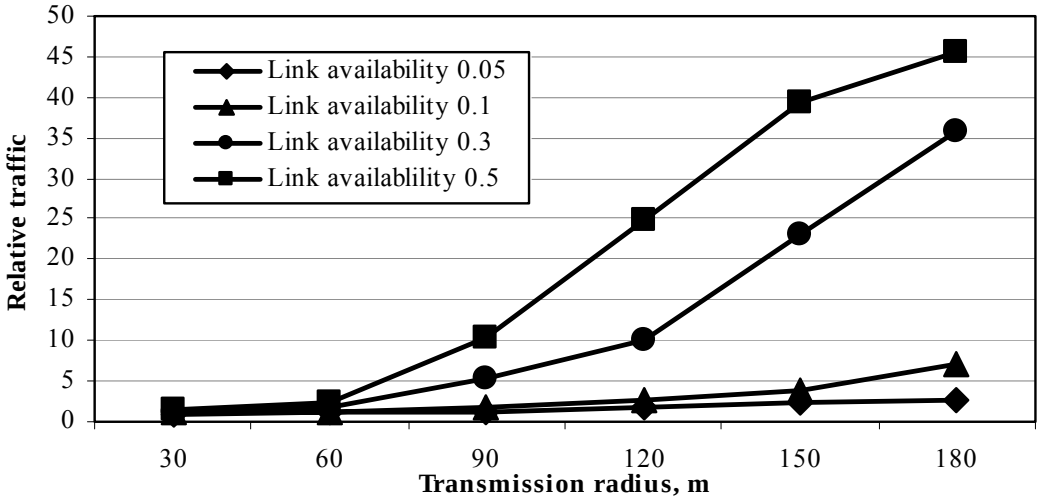

Figure 6.6 : Relative traffic, n_f , versus transmission radius with maximal node speed 14.4 km/h.

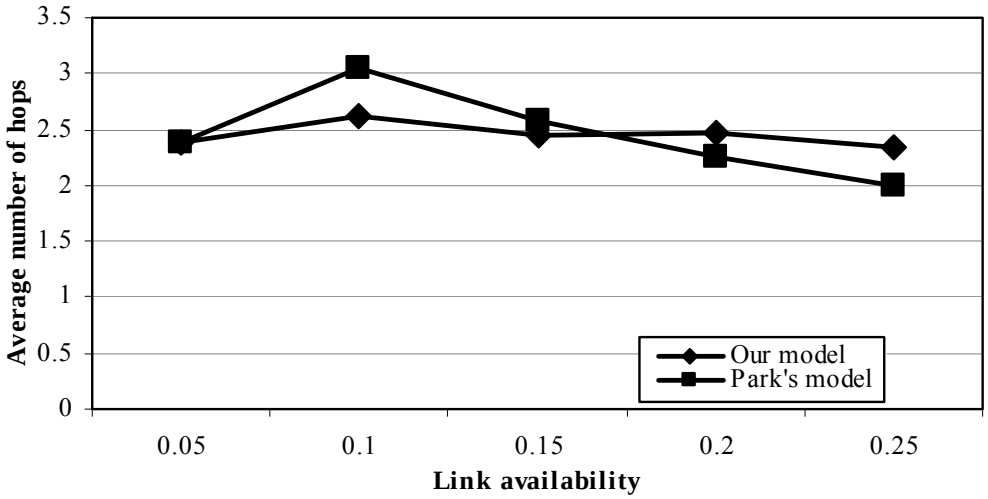

Figure 6.7 : Average number of hops, *h*, versus link availability with maximal node speed 3.6 km/h.

6.3 Average Values and Confidence Interval of the Investigated Performance Metrics

Average values and 95% confidence interval of investigated performance metrics versus transmission radius are provided in tables 6.11 – 6.18.

Table 6.11 : Average values and 95% confidence intervals of the performance metrics for speed S=14.4 and *l*=0.05

Metric	Transmission Radius, m					
	30	60	90	120	150	180
Average number of hops	0.75 ± 0.795	1.042 ± 0.133	1.807 ± 1.018	2.129 ± 0.323	2.332 ± 0.274	2.223 ± 0.205
Delivery ratio	0.001 ± 0.001	0.002 ± 0.001	0.006 ± 0.005	0.016 ± 0.006	0.023 ± 0.006	0.042 ± 0.008
Relative traffic	1.031 ± 0.015	1.149 ± 0.074	1.289 ± 0.148	1.745 ± 0.165	2.138 ± 0.267	2.915 ± 0.151

Table 6.12 : Average values and 95% confidence intervals of the performance metrics for speed S=14.4 and *l*=0.1

Metric	Transmission Radius, m					
	30	60	90	120	150	180
Delivery ratio	0.002 ± 0.002	0.004 ± 0.004	0.016 ± 0.008	0.03 ± 0.011	0.061 ± 0.003	0.140 ± 0.022
Relative traffic	1.09 ± 0.104	1.223 ± 0.062	1.705 ± 0.153	2.366 ± 0.325	3.755 ± 0.221	7.055 ± 0.511

Table 6.13 : Average values and 95% confidence intervals of the performance metrics for speed S=14.4 and *l*=0.3

Metric	Transmission Radius, m					
	30	60	90	120	150	180
Delivery ratio	0.004 ± 0.001	0.022 ± 0.013	0.079 ± 0.037	0.221 ± 0.081	0.489 ± 0.066	0.725 ± 0.1
Relative traffic	1.174 ± 0.115	1.877 ± 0.471	4.477 ± 1.488	10.803 ± 3.750	22.682 ± 2.964	33.144 ± 6.159

Table 6.14 : Average values and 95% confidence intervals of the performance metrics for speed S=14.4 and *l*=0.5

Metric	Transmission Radius, m					
	30	60	90	120	150	180
Average number of hops	1.228 ± 0.197	1.685 ± 0.251	2.883 ± 0.249	3.8 ± 0.068	3.66 ± 0.139	3.069 ± 0.168
Delivery ratio	0.007 ± 0.005	0.028 ± 0.014	0.148 ± 0.088	0.528 ± 0.028	0.855 ± 0.045	0.946 ± 0.009
Relative traffic	1.291 ± 0.136	2.491 ± 0.247	7.759 ± 3.095	23.661 ± 1.691	38.827 ± 1.866	45.44 ± 0.831

Table 6.15 : Average values and 95% confidence intervals of the performance metrics for speed S=3.6 and *l*=0.05

Metric	Transmission Radius, m					
	30	60	90	120	150	180
Average number of hops	1.098 ± 0.311	1.474 ± 0.926	1.622 ± 0.519	1.895 ± 0.689	2.101 ± 0.386	2.168 ± 0.369
Delivery ratio	0.002 ± 0.000	0.004 ± 0.005	0.008 ± 0.003	0.014 ± 0.004	0.026 ± 0.002	0.043 ± 0.008
Relative traffic	1.028 ± 0.033	1.176 ± 0.188	1.412 ± 0.136	1.644 ± 0.206	2.254 ± 0.181	3.161 ± 0.147

Table 6.16 : Average values and 95% confidence intervals of the performance metrics for speed S=3.6 and *l*=0.1

Metric	Transmission Radius, m					
	30	60	90	120	150	180
Delivery ratio	0.001 ± 0.001	0.006 ± 0.002	0.013 ± 0.008	0.028 ± 0.006	0.069 ± 0.024	0.128 ± 0.050
Relative traffic	1.033 ± 0.014	1.257 ± 0.103	1.61 ± 0.341	2.243 ± 0.138	4.262 ± 1.297	6.845 ± 2.226

Table 6.17 : Average values and 95% confidence intervals of the performance metrics for speed S=3.6 and *l*=0.3

Metric	Transmission Radius, m					
	30	60	90	120	150	180
Delivery ratio	0.004 ± 0.004	0.017 ± 0.011	0.074 ± 0.035	0.197 ± 0.068	0.527 ± 0.015	0.782 ± 0.060
Relative traffic	1.215 ± 0.213	1.856 ± 0.710	4.719 ± 1.976	9.574 ± 3.597	23.65 ± 1.697	33.144 ± 2.249

Table 6.18 : Average values and 95% confidence intervals of the performance metrics for speed S=3.6 and l=0.5

Metric	Transmission Radius, m					
	30	60	90	120	150	180
Average number of hops	1.275 ± 0.331	1.824 ± 0.435	3.097 ± 0.645	3.716 ± 0.302	3.771 ± 0.503	3.188 ± 0.383
Delivery ratio	0.006 ± 0.010	0.041 ± 0.026	0.161 ± 0.051	0.582 ± 0.063	0.856 ± 0.070	0.942 ± 0.053
Relative traffic	1.275 ± 0.303	2.827 ± 1.165	8.022 ± 1.729	25.998 ± 3.956	38.408 ± 4.563	44.97 ± 3.491

6.4 Discussion of the Simulation Results

The following comments and observations can be driven from the obtained results of simulation.

1. Clearly, the strong dependence of all chosen performance metrics on the transmission radius is observed. Where the nature of this dependence is different for different metrics.
2. As Figs. 6.1 and 6.4 demonstrate, the delivery ratio is quite low for small transmission radius of 30 m. However with the increase of the transmission radius the delivery ratio increases as well, and approaches to its highest value of one at high transmission radius of 180 m, when the link availability l = 0.5. For small link availability l = 0.05, the delivery ratio remains quite low even at high transmission radius of 180 m, as most of the packets will be lost during transmission from source node to destination nodes.
3. At a small transmission radius of 30 m, the delivery ratio remains quite low, even for a high link availability l = 0.5. This can be explained as follows; in a network of N = 50 nodes, there is a high probability that a transmitting or forwarding

node does not have any neighbors within its transmission radius. Using expression (3.3), it can be found that the probability of having two nodes in a circle of A which has radius if 30 m, with $\lambda = N/(500^2)$ nodes/m^2 and $S_R(A) = \pi 30^2$ m^2, is only 0.091. Consequently, a packet transmitted by some node has a very low change to be received by at least one neighbor node in the area of A.

4. As Figs. 6.2 and 6.5 show, the average number of hops is quite low for small values of transmission radius, increases up to a peak value with the increase of the transmission radius, and starts to decrease when the transmission radius become large. The explanation of such a behavior of this metric can be done as follows. Many transmitted or forwarded packets are lost and only those of them that are destined to close nodes, with small number of hops, will be delivered when the transmission radius is low, especially with small link availability. This will reduce the average number of hops. However in the case of large transmission radius, the destination nodes, for many transmitted packets, will be found in the area of only one transmission, where in this case the average number of hops is reduced as well.
5. Relative traffic, the third performance metric, can be quite low for small transmission radius, but with the increase of the transmission radius, especially with high link availability, it can be quite high, as shown in Figs. 6.3 and 6.6. Since more and more nodes are involved in the process of retransmission of packets. The relative traffic can be reduced by using smaller values for TTL. Since, in our experiments, the average number of hops is less than four and

considering the confidence interval as well, the TTL can be set at 5. The other way to reduce relative traffic, which will constitute a topic of our further research, is to use a more efficient routing protocol.

6. The change of maximum possible node speed, in the range from low speed of 3.6 km/h to medium speed of 14.4 km/h, doesn't result in considerable change of values of performance metrics.
7. As Fig. 6.7 demonstrates, the comparison of average number of hops with Park's model shows that, with small link availability, in terms of average number of hops, our model performs better than Park's model. But with the increase of the link availability, Park's model results in slightly lower average number of hops. This is a consequence of one of Park's assumptions. In their experiments, a full connected graph is assumed, where each of the nodes are connected to each other. This is not a realistic assumption and decreases the average number of hops. Being more realistic, the behavior of our model, in terms of average number of hops, is more stable as well.

Chapter 7

CONCLUSION

A simulation model of mobile ad hoc networks has been developed and its most significant performance metrics were investigated. In the model, a novel and more realistic scheme of inter-node communication links, which implies that each node has several orientation-dependent communication channels, is proposed. The behaviour of each channel is represented as a continuous-time Markov process.

A class of extended Petri nets were used to implement the model. In order to simplify the model, a virtual, centralized switching component is used. This component performs all switching operations, computes random movement of nodes and determines potentially reachable nodes for each transmitted packet as well as providing a great benefit by drastically reducing the number of connections required for each node.

A large number of simulation runs were conducted in an attempt to investigate the dependence of performance metrics on transmission radius, link availability and maximal node speed. As a result, total of 222 simulation experiments were run and a vast amount of raw data, (22200 values out of 222 tables), is analyzed.

The developed model implements basic functions of ad hoc networks and a novel and more realistic scheme of inter-node communication. The routing scheme of the

existing model is based on flooding technique. This is a reliable technique but, as investigated, the relative traffic is quite high, which results in many useless/duplicated messages.

Throughout the study of this thesis, we have found a chance to compare the performance of our model, in terms of average number of hops, with similar experiments conducted in [25].

The present model can be extended in a number of possible ways. The first way of extension is to allow leaving and joining of some nodes from/to the network, as the simulation progresses. Allowing many nodes to generate messages and modelling of complete failure of nodes, are respectively the second and third ways of extension. And the fourth and very significant way of extension can be the implementation of a more efficient routing scheme.

The entire model, together with the proposed scheme can be used for study of all aspects of information dissemination and routing protocols, in wireless mobile ad hoc networks.

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APPENDICES

Appendix A: The source text of the model of the switching module.

```
(*************************************************************************)
(*                            Switching module                           *)
(*              for the model of an ad-hoc wireless network              *)
(*            with directional inter-node communication links            *)
(*                                                                       *)
(*            File  SWITCH.JOM             Date 12 March 2009            *)
(*************************************************************************)
SEGMENT SWITCH, TICK = MSEC;
ATTRIBUTES
    MTYP: INTEGER;    (* Message type: 1 - initilizing info from this module,
                                       2 - request message from a node
                                       3 - reply  message,
                                       4 - unicast data packet,
                                       5 - multicast data packet           *)
    SRC : INTEGER;                  (* Originating (source) node of message *)
    DEST: INTEGER;                        (* Destination node of message *)
    SNDR: INTEGER;   (* If MTYP > 1, immediate sending node of this message *)
    NEXT: INTEGER;                      (* ID of next node to pass message *)
    MID : INTEGER;         (* Message ID: 1, 2, ... ; incremented by source *)
    NONB: INTEGER;                                (* Working attribute *)
    XCD : REAL;                        (* X-coordinate of immediate sender *)
    YCD : REAL;                        (* Y-coordinate of immediate sender *)
    RX  : REAL;                               (* X-coordinate of receiver *)
    RY  : REAL;                               (* Y-coordinate of receiver *)
    TTL : INTEGER;               (* The number of hops for message to pass *)
    HOPS: INTEGER;          (* The number of hops already passed by message *)
    ND1 : INTEGER;             (* Id of the first passed node (source node) *)
    ND2 : INTEGER;                        (* Id of the second passed node *)
    ND3 : INTEGER;                         (* Same for other passed nodes *)
    ND4 : INTEGER;
    ND5 : INTEGER;
    ND6 : INTEGER;
    ND7 : INTEGER;
    ND8 : INTEGER;
    ND9 : INTEGER;
    ND10: INTEGER;
    ND11: INTEGER;
    ND12: INTEGER;

DATA
    PDIR /0.0/: REAL;   (* Probability to change direction of node movement *)
    NODS /0/: INTEGER;                (* Total number of nodes in the area *)
    XMIN /0.0/: REAL;                  (* Minimal X-coordinate of the area *)
    XMAX /0.0/: REAL;                  (* Maximal X-coordinate of the area *)
    YMIN /0.0/: REAL;                  (* Minimal Y-coordinate of the area *)
    YMAX /0.0/: REAL;                  (* Maximal Y-coordinate of the area *)
    DX /0.0/:   REAL;                     (*  Max step size in X-direction *)
    DY /0.0/:   REAL;                     (*  Max step size in Y-direction *)
    XNEW /0.0/: REAL;                (* New node coordinate in X-direction *)
    YNEW /0.0/: REAL;                (* New node coordinate in Y-direction *)
    DT /0.0/: REAL;                    (* Time  to recompute node position *)
    IDNU /0/: INTEGER;                      (* Counter of node identifiers *)
    DMAX /0.0/: REAL;                              (* Transmission radius *)
    CNT /0/: INTEGER;        (* Counter of nodes within transmission radius *)
    XPOS: ARRAY [50] OF REAL;             (* Current X-coordonates of nodes *)
    YPOS: ARRAY [50] OF REAL;             (* Current Y-coordonates of nodes *)
```

```
    XNXT: ARRAY [50] OF REAL;                          (* Next X-coordinate *)
    YNXT: ARRAY [50] OF REAL;                          (* Next Y-coordinate *)
    DIST: ARRAY [49] OF INTEGER;                        (* IDs of neighbors *)

(* Pascal section with  working variables *)
INTERFACE
IMPLEMENTATION
var
   inod: integer;                                            (* Node index *)
   OK,j,i: integer;                                    (* Flag and indexes *)
   xi, yi: real;                                      (* Working variables *)
   dxx, dyy: real;              (* Coordinate difference between two nodes *)
   dis: real;                                 (* Distance between two nodes *)
   prob: real;                                 (* Value of function FRANDOM *)
END.

(* Preparation of an initializing info  for all nodes and
   generation of initial positions of  nodes in given area *)
NET   T4: S4/S3, S5;
TRANS T4: %S5.MTYP := 1;                                (* Service messge type *)
          %S5.NONB := %NODS;  (* Inform each node about the number of nodes *)
          (* Writeln('SWITCH: Initial node positions:'); *)

          (* Specification of initial and next positions of nodes *)
          for inod := 1 to %NODS do
          BEGIN
          %XPOS[inod] := UNIFRM (1, %XMIN, %XMAX);
          %YPOS[inod] := UNIFRM (1, %YMIN, %YMAX);
          %XNXT[inod] := UNIFRM (1, %XPOS[inod] - %DX, %XPOS[inod] + %DX);
          %YNXT[inod] := UNIFRM (1, %YPOS[inod] - %DY, %YPOS[inod] + %DY);
         if (%XNXT[inod] < %XMIN) then %XNXT[inod] := %XMIN;
         if (%XNXT[inod] > %XMAX) then %XNXT[inod] := %XMAX;
         if (%YNXT[inod] < %YMIN) then %YNXT[inod] := %YMIN;
          if (%YNXT[inod] > %YMAX) then %YNXT[inod] := %YMAX;
         (* Writeln('Ndpos ', inod, ':', %XPOS[inod], ' ', %YPOS[inod]); *)
          (* Writeln('Ndnxt ', inod, ':', %XNXT[inod], ' ', %YNXT[inod]); *)
          END;

          (* Writeln('============================================ '); *)

(* Periodical re-computing of positions of all nodes in the area *)
NET   Y1: S3, S2/S1;
NET   T1: S1/S2;
TIME  T1: %DELAY := %DT;
TRANS T1:                          (* Re-computing after elapsing step time *)
          for inod := 1 to %NODS do
          BEGIN
          prob := FRANDOM(1);
          xi := %XNXT[inod] + (%XNXT[inod] - %XPOS[inod]);
          yi := %YNXT[inod] + (%YNXT[inod] - %YPOS[inod]);
          if (prob < %PDIR) OR (xi < %XMIN) OR       (* Change of direction *)
          (xi > %XMAX) OR (yi < %YMIN) OR (yi > %YMAX)  (* Boundary reached *)
          then                                      (* Compute new direction *)
            BEGIN
            OK := 0;                           (* Init flag for X-coordinate *)
            WHILE (OK = 0) do          (* Determine new X-coodinate of node *)
              BEGIN
              xi := UNIFRM (1, %XNXT[inod] - %DX, %XNXT[inod] + %DX);
              if (xi > %XMIN) AND (xi < %XMAX)
              then BEGIN %XPOS[inod] := %XNXT[inod];
              %XNXT[inod]:= xi; OK := 1; END;
              END;
            OK := 0;                           (* Init flag for Y-coordinate *)
```

```
            WHILE (OK = 0) do          (* Determine new Y-coodinate of node *)
              BEGIN
              yi := UNIFRM (1, %YNXT[inod] - %DY, %YNXT[inod] + %DY);
              if (yi > %YMIN) AND (yi < %YMAX)
              then BEGIN %YPOS[inod] := %YNXT[inod];
              %YNXT[inod] := yi; OK := 1; END;
              END;

              (* Writeln('Nd ', inod, ':', %XPOS[inod],' ', %YPOS[inod]); *)
            END
            else                              (* Move in the same direction *)
             BEGIN
             %XPOS[inod] := %XNXT[inod]; %XNXT[inod] := xi;      (* Along X *)
             %YPOS[inod] := %YNXT[inod]; %YNXT[inod] := yi;      (* Along Y *)
             END;

            (* Writeln('Nd ', inod, ':', %XPOS[inod],' ', %YPOS[inod]); *)
            (* Writeln('Nd ', inod, ':', %XNXT[inod],' ', %YNXT[inod]); *)
          END; (* External loop *)

          (* Writeln ('++++++++++++++++++++++++++++'); *)


(* Inputs to swithing module from nodes *)
NET  Y1000: s101,s102,s103,s104,s105,s106,s107,s108,s109,s110,
            s111,s112,s113,s114,s115,s116,s117,s118,s119,s120,
            s121,s122,s123,s124,s125,s126,s127,s128,s129,s130,
            s131,s132,s133,s134,s135,s136,s137,s138,s139,s140,
            s141,s142,s143,s144,s145,s146,s147,s148,s149,s150/Q1000;

(* Handling the request from a node to pass a message to neighbor nodes *)
NET   T1000: Q1000, S1000/S501;
TRANS T1000: i := %Q1000.SNDR;                 (* ID of the requesting node *)
             %CNT := 0;
             %S501.XCD := %XPOS[i];  (* X-coordinate of the requesting node *)
             %S501.YCD := %YPOS[i];  (* Y-coordinate of the requesting node *)
             for j :=1 to %NODS do  (* Determing neighbors of the requester *)
             BEGIN
               if i<> j
               then BEGIN
                    (*writeln('i= ', i, '  j= ', j);*)
                    dxx := %XPOS[i] - %XPOS[j];
                    dyy := %YPOS[i] - %YPOS[j];
                    dis := sqrt(dxx*dxx + dyy*dyy);  (* Distan to next node *)
                    if dis < %DMAX        (* Node j is in the coverage area *)
                    then BEGIN
                    (* Writeln('Dis    i    j', dis, '   ',i,'   ', j); *)
                         %CNT := %CNT + 1;               (* Count the node *)
                         %DIST[%CNT] := j;                 (* Store its ID *)
                         END;
                    END;
             END;  (* External loop *)
             (* Writeln('T1000:DIST array ', %DIST[%CNT]); *)

NET Y500: S500, S501/S502;              (* Passing the message to neighbors *)
NET X502: S502/S503, S1000;
CONTR X502: IF %CNT = 0
            THEN %OUT := 2               (* Message passed to all neighbors *)
            ELSE %OUT := 1;                                    (* Not yet *)
NET T503: S503/S11, S500;       (* Prepare to pass message to next neighbor *)
TRANS T503: i := %DIST[%CNT];                          (* ID of the neighbor *)
            %S11.NEXT := i;
            %CNT := %CNT - 1;
```

```
            %S11.RX := %XPOS[i];            (* Coordinate of receiving node *)
            %S11.RY := %YPOS[i];
            (* Writeln('T503:DIST array ', %DIST[%CNT]); *)
            (* WRITELN('SWITCH: Nd ', %S11.SNDR, ' --> ', %S11.NEXT); *)

(* Initial distribution of identifiers to nodes *)
NET   Y2: S5, S6/S7;
TRANS Y2: %IDNU := %IDNU + 1;        (* Id for the next node, can be > NODS *)
          %S7.NEXT := %IDNU;          (* Store Id of next node in attribute *)

NET   X2: S7/S8, S9;
CONTR X2: IF %IDNU <= %NODS                          (* All IDs distributed? *)
          THEN %OUT := 1                        (* Not yet, next Id message *)
          ELSE Begin
               %IDNU := %NODS;                       (* Restore maximal Id *)
               %OUT := 2;                               (* Finish the loop *)
               End;
NET   T8: S8/S10, S6;                                          (* Looping *)
NET   T9: S9;                                                (* Absorb token *)
NET   Y3: S10, S11/S2000;                         (* Prepare to pass message *)

(* Passing a message to a node with ID = S2000.NEXT *)
NET   X2000: s2000/s201,s202,s203,s204,s205,s206,s207,s208,s209,s210,
s211,s212,s213,s214,s215,s216,s217,s218,s219,s220,
s221,s222,s223,s224,s225,s226,s227,s228,s229,s230,
s231,s232,s233,s234,s235,s236,s237,s238,s239,s240,
s241,s242,s243,s244,s245,s246,s247,s248,s249,s250;
CONTR X2000: %OUT := %S2000.NEXT;

(* Attaching copies of the node segment MONOD to the switching segment *)
ATTACH MONOD/NOD1,NOD2,NOD3,NOD4,NOD5, NOD6, NOD7, NOD8, NOD9, NOD10,
NOD11, NOD12, NOD13, NOD14, NOD15, NOD16, NOD17, NOD18, NOD19, NOD20,
NOD21, NOD22, NOD23, NOD24, NOD25, NOD26, NOD27, NOD28, NOD29, NOD30,
NOD31, NOD32, NOD33, NOD34, NOD35, NOD36, NOD37, NOD38, NOD39, NOD40,
NOD41, NOD42, NOD43, NOD44, NOD45, NOD46, NOD47, NOD48, NOD49, NOD50/;

(* Linking switching segment  with node segments (copies of MONOD) *)
LINK SWITCH,NOD1:  S101,S100/S201,S200;
LINK SWITCH,NOD2:  S102,S100/S202,S200;
LINK SWITCH,NOD3:  S103,S100/S203,S200;
LINK SWITCH,NOD4:  S104,S100/S204,S200;
LINK SWITCH,NOD5:  S105,S100/S205,S200;
LINK SWITCH,NOD6:  S106,S100/S206,S200;
LINK SWITCH,NOD7:  S107,S100/S207,S200;
LINK SWITCH,NOD8:  S108,S100/S208,S200;
LINK SWITCH,NOD9:  S109,S100/S209,S200;
LINK SWITCH,NOD10: S110,S100/S210,S200;
LINK SWITCH,NOD11: S111,S100/S211,S200;
LINK SWITCH,NOD12: S112,S100/S212,S200;
LINK SWITCH,NOD13: S113,S100/S213,S200;
LINK SWITCH,NOD14: S114,S100/S214,S200;
LINK SWITCH,NOD15: S115,S100/S215,S200;
LINK SWITCH,NOD16: S116,S100/S216,S200;
LINK SWITCH,NOD17: S117,S100/S217,S200;
LINK SWITCH,NOD18: S118,S100/S218,S200;
LINK SWITCH,NOD19: S119,S100/S219,S200;
LINK SWITCH,NOD20: S120,S100/S220,S200;
LINK SWITCH,NOD21: S121,S100/S221,S200;
LINK SWITCH,NOD22: S122,S100/S222,S200;
LINK SWITCH,NOD23: S123,S100/S223,S200;
LINK SWITCH,NOD24: S124,S100/S224,S200;
LINK SWITCH,NOD25: S125,S100/S225,S200;
LINK SWITCH,NOD26: S126,S100/S226,S200;
```

```
LINK SWITCH,NOD27: S127,S100/S227,S200;
LINK SWITCH,NOD28: S128,S100/S228,S200;
LINK SWITCH,NOD29: S129,S100/S229,S200;
LINK SWITCH,NOD30: S130,S100/S230,S200;
LINK SWITCH,NOD31: S131,S100/S231,S200;
LINK SWITCH,NOD32: S132,S100/S232,S200;
LINK SWITCH,NOD33: S133,S100/S233,S200;
LINK SWITCH,NOD34: S134,S100/S234,S200;
LINK SWITCH,NOD35: S135,S100/S235,S200;
LINK SWITCH,NOD36: S136,S100/S236,S200;
LINK SWITCH,NOD37: S137,S100/S237,S200;
LINK SWITCH,NOD38: S138,S100/S238,S200;
LINK SWITCH,NOD39: S139,S100/S239,S200;
LINK SWITCH,NOD40: S140,S100/S240,S200;
LINK SWITCH,NOD41: S141,S100/S241,S200;
LINK SWITCH,NOD42: S142,S100/S242,S200;
LINK SWITCH,NOD43: S143,S100/S243,S200;
LINK SWITCH,NOD44: S144,S100/S244,S200;
LINK SWITCH,NOD45: S145,S100/S245,S200;
LINK SWITCH,NOD46: S146,S100/S246,S200;
LINK SWITCH,NOD47: S147,S100/S247,S200;
LINK SWITCH,NOD48: S148,S100/S248,S200;
LINK SWITCH,NOD49: S149,S100/S249,S200;
LINK SWITCH,NOD50: S150,S100/S250,S200;

SEGEND.
```

Appendix B: The source text of the model of a node module.

```
(*************************************************************************)
(*                            Node module                                *)
(*                  for the model of an ad-hoc network                   *)
(*            with directional inter-node communication links            *)
(*                                                                       *)
(*                                                                       *)
(*            File  MONOD.JOM               Date  12 March  2009        *)
(*************************************************************************)
SEGMENT MONOD, TICK = MSEC;
ATTRIBUTES
    MTYP: INTEGER;    (* Message type: 1 - initializing info from SWITCH,
                                       2 - request message,
                                       3 - reply  message,
                                       4 - unicast data packet,
                                       5 - multicast data packet          *)
    SRC : INTEGER;                                (* Source node of message *)
    DEST: INTEGER;                             (* Destination node of message *)
    SNDR: INTEGER;             (* If MTYP > 1, sending node of this message *)
    NEXT: INTEGER;                              (* Next node to pass message *)
    MID : INTEGER;         (* Message Id: 1, 2, ... ; incremented by source *)
    NONB: INTEGER;                                   (* Working attribute *)
    XCD : REAL;                                   (* X-coordinate of sender *)
    YCD : REAL;                                   (* Y-coordinate of sender *)
    RX  : REAL;                                (* X-coordinate of receiver *)
    RY  : REAL;                                (* Y-coordinate of receiver *)
    TTL : INTEGER;               (* The number of hops for message to pass *)
    HOPS: INTEGER;          (* The number of hops already passed by message *)
    ND1 : INTEGER;             (* Id of the first passed node (source node) *)
    ND2 : INTEGER;                          (* Id of the second passed node *)
    ND3 : INTEGER;                           (* Same for other passed nodes *)
    ND4 : INTEGER;
    ND5 : INTEGER;
    ND6 : INTEGER;
    ND7 : INTEGER;
    ND8 : INTEGER;
    ND9 : INTEGER;
    ND10: INTEGER;
    ND11: INTEGER;
    ND12: INTEGER;

DATA
    SELF /0/: INTEGER;                              (* Unique Id of this node *)
    GRID /0/: INTEGER;                  (* Group (multicast) Id of this node *)
    MNUM /0/: INTEGER;                     (* Counter of message identifiers *)
    TSRC /0.0/: REAL;         (* Sleep time of source node between messages *)
    NODS /0/: INTEGER;                        (* Number of nodes in the area *)
    PASS /0/: INTEGER;       (* A flag: 1 - message passed the node already *)
    PLOS /0.0/: REAL;  (* Probability of message loss by the node, not used *)
    MSGS: ARRAY [20] of INTEGER;(* Sliding window of Ids of recent messages *)
    IMID /0/: INTEGER;              (* Counter of messages ID in array MSGS *)
    NEW /0/ : INTEGER;                               (* Flag of a new message *)
    RMIN /0.0/: REAL;        (* Min distance to a close node, reliable link *)
    RMAX /0.0/: REAL;        (* Max distance to a close node, reliable link *)
    TON /0.0/: REAL;                        (* Mean time of link in ON state *)
    TOFF /0.0/: REAL;                      (* Mean time of link in OFF state *)
    TREC /0.0/: REAL;                  (* Period of checking of link states *)
```

```
    DNUM /8/: INTEGER;      (* The number of directional links of each node *)
    TTLM /7/: INTEGER;                                    (* Maximal TTL *)
    DILS: ARRAY [8] OF INTEGER;         (* States of links: 1 - ON, 0 - OFF *)
    TLS: ARRAY [8] OF REAL;        (* Moments of state termination of links *)

(* Pascal section with  working variables *)
INTERFACE
IMPLEMENTATION
var
   inod,i: integer;                                          (* Node index *)
   ind: integer;                                          (* Working index *)
   OK:   integer;                                               (* A flag *)
   xi, yi: real;                                      (* Working variables *)
   prob : real;                                        (* Value of FRANDOM *)
   curtime: real;                                 (* Current simulation time *)
   dist :real;                 (* Distance from receiving to sending node  *)
   dxx, dyy : real;                               (* Coordinate differencies *)
   tang : real;          (* Tangent of angle from receiving to sending node *)
END.

(* Input from the switching segment *)
NET   X1: s200/s1, s2;
CONTR X1: IF %S200.MTYP = 1
          THEN %OUT := 1                    (* Initializing info for a node *)
          ELSE %OUT := 2;                     (* A packet from another node *)

NET   T1: S1/S40,S4;             (* Obtained info from the switching module *)
TRANS T1: %NODS := %S1.NONB;                 (* The number of nodes in area *)
          %SELF := %S1.NEXT;                          (* I got my identifier *)
          (* WRITELN ('My Id = ', %SELF); *)
          (* Random initializing of link states and times *)
          for i := 1 to %DNUM do
          BEGIN                                                 (* Next link *)
          prob := FRANDOM (2);
          if prob < 0.5
          then begin                          (* ON link state in direction i *)
               %DILS[i] := 1;
               %TLS[i] := EXPON (2, %TON)
               end
          else begin                         (* OFF link state in direction i *)
               %DILS[i] := 0;
               %TLS[i] := EXPON (2, %TOFF)
               end
          END;

(* Periodic checking and changing of link states *)
NET   Y40: S40, S42/S41;
NET   T41: S41/S42;
TIME  T41: %DELAY := %TREC;                                        (* Period *)
TRANS T41: curtime := CLOCK(1);
           for i := 1 to %DNUM do
           BEGIN
           if curtime >= %TLS[i]     (* If link state terminated, change it *)
           then BEGIN
                if %DILS[i] = 1                          (* It was ON state *)
                then begin
                     %DILS[i] := 0;
                     %TLS[i] := curtime + EXPON(3, %TOFF)
                     end
                else begin                                (* It was OFF state *)
                     %DILS[i] := 1;
                     %TLS[i] := curtime + EXPON(4, %TON)
                     end
```

```
              END
            else continue;                          (* No change for link i *)
            END;

NET   X4: S4/S5, S6;
CONTR X4: if %SELF = 1                  (* Only node 1 may be a source node *)
          then %OUT := 1
          else %OUT := 2;
NET   T6: S6;                               (* Absorber for all other nodes *)

(* Periodic transmission of packets by source node *)
NET   Y5: S5, S98/S96;
NET   T5: S96/S97,;
TIME  T5: %DELAY := %TSRC;               (* Period of generation of packets *)
TRANS T5: %S97.MTYP := 2;                                (* A request message *)
          %S97.SRC := 1;                                    (* Source node Id *)
          %S97.DEST := IUNIFR (1, 2, %NODS);  (* Random Choice of dest node *)
          %S97.SNDR := 1;                          (* ID of immediate sender *)
          %S97.TTL  := %TTLM;
          %S97.HOPS := 0;
          %S97.ND1 := 1;         (* List of passed nodes starts with node 1 *)
          %MNUM := %MNUM + 1;                               (* Packet number *)
          %S97.MID := %MNUM;
NET   T999: S97/S999, S98;


(* Handling  a received message *)
NET   X2: S2/Q1, S3, S31;
CONTR X2: if %SELF = 1
          then %OUT := 2               (* Node 1 discards received messages *)
          else BEGIN   (* Did the  messages come via close node or ON link? *)
              dxx := %S2.XCD - %S2.RX;
                dyy := %S2.YCD - %S2.RY;
              dist := sqrt (dxx * dxx + dyy * dyy);
                if dist <= UNIFRM (1, %RMIN, %RMAX)
                then %OUT := 1 (* Accept from a close node *)
                else begin                                (* Determine a link  *)
                     tang := dyy/(dxx + 0.1);             (* Direction angle *)
            if (tang >= 0.0) AND (tang <= 1.0) AND (dxx > 0) AND (dyy >= 0)
            then i := 1                          (* First directional sector *)
            else
            if (tang > 1.0) AND (dxx > 0) AND (dyy >= 0)
            then i := 2                              (* 2nd directional sector *)
            else
            if (tang <= -1.0) AND (dxx < 0) AND (dyy >= 0)
            then i := 3                              (* 3rd directional sector *)
            else
            if (tang > -1.0) AND (tang <= 0) AND (dxx < 0) AND (dyy >= 0)
            then i := 4                              (* 4th directional sector *)
            else
            if (tang > 0) AND (tang <= 1.0) AND (dxx < 0) AND (dyy < 0)
            then i := 5                              (* 5th directional sector *)
            else
            if (tang > 1.0) AND (dxx < 0) AND (dyy < 0)
            then i := 6                              (* 6th directional sector *)
            else
            if (tang <= -1.0) AND (dxx > 0) AND (dyy < 0)
            then i := 7                              (* 7th directional sector *)
            else i := 8                              (* 8th directional sector *)
                    end;                                    (* Determine a link *)
               if %DILS[i] = 1                                   (* Link is ON *)
               then %OUT := 1                             (* Accept message *)
               else %OUT := 3          (* Link is OFF, discard the message *)
```

```
              END;
NET   T3: S3;               (* Discarding the message if received by node 1 *)
NET   T31: S31;                      (* Lost message, it came from OFF link *)

(* Handling  the received message by nodes 2, 3, ..., NODS *)
NET   T2: Q1/S9;
TRANS T2: %S9.TTL := %S9.TTL - 1;
          %S9.HOPS := %S9.HOPS + 1;
         if %IMID = 0                              (*The 1st message of all*)
         then BEGIN
              %IMID := 1; %NEW := 1;
              %MSGS[1] := %S9.MID;
              END
         else BEGIN
              if %S9.MID = %MSGS[1]
              then %NEW := 0                         (* Dublicated message *)
              else begin
                    %NEW := 1;
                 %MSGS[1] := %S9.MID;
                 end
              END;
           (* WRITELN('Nd ', %SELF, ' from ', %S9.SNDR, ' MID = ', %S9.MID); *)

(* Decision on the received message *)
NET   X3: S9/S7, S8, S10, S11;
CONTR X3: %OUT := 1;                       (* Forward the message on default *)
          if (%S9.TTL = 0) AND (%S9.DEST <> %SELF)
          then %OUT := 2                (* Discard the message with TTL = 0 *)
          else BEGIN
              if %NEW = 0
               then %OUT := 3              (* Dublicated message, disard it *)
              else if (%S9.DEST = %SELF) AND (%NEW = 1)
                    then %OUT := 4    (* Delivered new message to dest node *)
               END;
NET   T8: S8;                         (* Discarding the  message with TTL = 0 *)
NET   T10: S10;                          (* Discarding the duplicated message *)
NET   T11: S11;                (* Message received by this destination node *)

(* TRANS T11:
WRITELN('DEST NODE:', %SELF);
WRITE('Route: ',%S11.ND1,' ',%S11.ND2,' ',%S11.ND3,' ',%s11.ND4);
WRITE(' ',%s11.ND5,' ',%S11.ND6,' ',%S11.ND7,' ',%S11.ND8);
WRITELN(' ',%S11.ND9,' ',%s11.ND10,' ',%s11.ND11,' ',%S11.ND12);            *)

(* Forwarding  the received message *)
NET   T1000: S7/S1000;
TIME  T1000: %DELAY := UNIFRM(1, 1.00, 30.00);    (* Transm and propag time *)
TRANS T1000: %S1000.SNDR := %SELF;                        (* Immediate sender *)
             %S1000.NONB := 1;     (* Retransmit to one node only, not used *)
(* Store ID of this node in first free attribute ND2 or ND3 or ... ND12 *)
             if %S1000.ND2 = 0
             then %S1000.ND2 := %SELF
             else if %S1000.ND3 = 0
             then %S1000.ND3 := %SELF
             else if %S1000.ND4 = 0
             then %S1000.ND4 := %SELF
             else if %S1000.ND5 = 0
             then %S1000.ND5 := %SELF
             else if %S1000.ND6 = 0
             then %S1000.ND6 := %SELF
             else if %S1000.ND7 = 0
             then %S1000.ND7 := %SELF
             else if %S1000.ND8 = 0
```

```
                then %S1000.ND8 := %SELF
                else if %S1000.ND9 = 0
                then %S1000.ND9 := %SELF
                else if %S1000.ND10 = 0
                then %S1000.ND10 := %SELF
                else if %S1000.ND11 = 0
                then %S1000.ND11 := %SELF
                else if %S1000.ND12 = 0
                then %S1000.ND12 := %SELF;

(* Node output *)
NET   Y1000: S999, S1000/S100;
SEGEND.
```

Appendix C: The file of parameters for a specific combination of model parameters.

```
(*************************************************************************)
(*                           MCL statements                              *)
(*                for the model of mobile ad-hoc network                 *)
(*             with directional inter-node communication links           *)
(*                                                                       *)
(*               File  SWITCH.JZP        Date 12 March 2009              *)
(*************************************************************************)

FOR SEGMENT SWITCH;

SET NODS /50/;                    (* The number of nodes in the given area *)
SET XMIN /0.0/;                        (* Minimal X-coordinate of the area *)
SET XMAX /500.0/;                      (* Maximal X-coordinate of the area *)
SET YMIN /0.0/;                        (* Minimal Y-coordinate of the area *)
SET YMAX /500.0/;                      (* Maximal Y-coordinate of the area *)
(* DX: 0.1 (3.6 km/h), 0.2 (7.2), 0.4 (14.4), 0.8 (28.8) and 1.6 (57.6)    *)
SET DX /0.4/;                       (* Max step along X during step time, m *)
SET DY /0.4/;                       (* Max step along Y during step time, m *)
SET DT /100.0/;               (* Step time to recompute node position, ms *)
SET DMAX /30.0/;                                 (* Transmission radius, m *)
SET PDIR /0.0/;        (* Probability to change direction of node movement *)
MARK S4;
MARK S1000;
STATISTICS Y1000, X2000, T8, T1000;

FOR SEGMENT NOD1;
SET TSRC /500.0/;         (* Time interval to send messages by source node *)


FOR SEGMENTS NOD1,NOD2,NOD3,NOD4,NOD5,NOD6,NOD7,NOD8,NOD9,
NOD10,NOD11,NOD12,NOD13,NOD14,NOD15,NOD16,NOD17,NOD18,NOD19,NOD20,
NOD21,NOD22,NOD23,NOD24,NOD25;

SET TON /10000.0/;              (* Mean time a link in ON state, ms, fixed *)

(* TOFF values for different values of link availability l:                *)
(* 190000 (l = 0.05), 90000 (0.1),56667 (0.15), 40000 (0.2), 30000 (0.25)  *)
(* 23333 (0.3), 18570 (0.35), 15000 (0.4), 12222 (0.45), 10000 (0.5)       *)

SET TOFF /190000.0/;    (* Mean time a link in OFF state, ms, for l = 0.05 *)
SET TREC /2000.0/;                  (* Interval of checking of link states *)
(* Parameters of uniform distribution of distance to very near nodes, m *)
SET RMIN /5.0/;
SET RMAX /10.0/;
STATISTICS T1000,T11,T999,T31,X2;
STATISTICS S100,S200,S1,S2,Q1,S7,S8,S10,S11, S31;
HISTO 1 (HOPS,0,1,7) s11;

FOR SEGMENTS NOD26,NOD27,NOD28,NOD29,NOD30,NOD31,NOD32,NOD33,NOD34,
NOD35,NOD36,NOD37,NOD38,NOD39,NOD40,NOD41,NOD42,NOD43,NOD44,NOD45,
NOD46,NOD47,NOD48,NOD49,NOD50;
```

```
SET TON /10000.0/;              (* Mean time a link in ON state, ms, fixed *)
SET TOFF /190000.0/;    (* Mean time a link in OFF state, ms, for l = 0.05 *)
SET TREC /2000.0/;                 (* Interval of checking of link states *)
(* Parameters of uniform distribution of distance to very near nodes, m *)
SET RMIN /5.0/;
SET RMAX /10.0/;
STATISTICS T1000,T11,T999,T31,X2;
STATISTICS S100,S200,S1,S2,Q1,S7,S8,S10,S11,S31;
HISTO 1 (HOPS,0,1,7) s11;
```

Appendix D: Raw data of a Simulation Run.

```
Simulation run name:     SWITCH
Date and time:           25 November 2009,  15:41:20
Head segment:            SWITCH (11/24/2009 10:21)
Other segments:
  NOD1   (11/24/2009 10:21)  NOD2   (11/24/2009 10:21)
  NOD3   (11/24/2009 10:21)  NOD4   (11/24/2009 10:21)
  NOD5   (11/24/2009 10:21)  NOD6   (11/24/2009 10:21)
  NOD7   (11/24/2009 10:21)  NOD8   (11/24/2009 10:21)
  NOD9   (11/24/2009 10:21)  NOD10  (11/24/2009 10:21)
  NOD11  (11/24/2009 10:21)  NOD12  (11/24/2009 10:21)
  NOD13  (11/24/2009 10:21)  NOD14  (11/24/2009 10:21)
  NOD15  (11/24/2009 10:21)  NOD16  (11/24/2009 10:21)
  NOD17  (11/24/2009 10:21)  NOD18  (11/24/2009 10:21)
  NOD19  (11/24/2009 10:21)  NOD20  (11/24/2009 10:21)
  NOD21  (11/24/2009 10:21)  NOD22  (11/24/2009 10:21)
  NOD23  (11/24/2009 10:21)  NOD24  (11/24/2009 10:21)
  NOD25  (11/24/2009 10:21)  NOD26  (11/24/2009 10:21)
  NOD27  (11/24/2009 10:21)  NOD28  (11/24/2009 10:21)
  NOD29  (11/24/2009 10:21)  NOD30  (11/24/2009 10:21)
  NOD31  (11/24/2009 10:21)  NOD32  (11/24/2009 10:21)
  NOD33  (11/24/2009 10:21)  NOD34  (11/24/2009 10:21)
  NOD35  (11/24/2009 10:21)  NOD36  (11/24/2009 10:21)
  NOD37  (11/24/2009 10:21)  NOD38  (11/24/2009 10:21)
  NOD39  (11/24/2009 10:21)  NOD40  (11/24/2009 10:21)
  NOD41  (11/24/2009 10:21)  NOD42  (11/24/2009 10:21)
  NOD43  (11/24/2009 10:21)  NOD44  (11/24/2009 10:21)
  NOD45  (11/24/2009 10:21)  NOD46  (11/24/2009 10:21)
  NOD47  (11/24/2009 10:21)  NOD48  (11/24/2009 10:21)
  NOD49  (11/24/2009 10:21)  NOD50  (11/24/2009 10:21)
File of MCL statements:  C:\Documents and Settings\Salahi
Developers\Desktop\master\EMU\RESEARCH\WINSIM\SimSystem\Winsim\Models\SWITCH.JZ
P
Simulation time:         1.001000E+006 ms
Starting time to collect statistics:  0.000000E+000

Segment: SWITCH
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  X2000  !    0  !  0.000000E+000 !   102455!  0.000000E+000 !
!     T8  !    0  !  0.000000E+000 !       50!  0.000000E+000 !
!  T1000  !    0  !  0.000000E+000 !     6215!  0.000000E+000 !
!  Y1000  !    0  !  0.000000E+000 !     6215!  0.000000E+000 !
-----------------------------------------------------------------
```

```
Segment: SWITCH.NOD1
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    T11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2386!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !     2002!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD1
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !     2002!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!     S7  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    S31  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2386!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2387!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD1
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !        0! 0.000000E+000!   0!
-------------------------------------------------------------

Segment: SWITCH.NOD1
                      Simulation time: 1.001000E+006 ms


Table number:     1              Average value: 0.000000E+000
Argument name: Attribute HOPS     Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000    Sample size:     0
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !    0.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !    0.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !    0.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !    0.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD2
```

Simulation time: 1.001000E+006 ms

Transition	State	Utilization	Firings #	Mean firing time
T1000	0	7.103725E-004	39	1.823289E+001
T11	0	0.000000E+000	0	0.000000E+000
T31	0	0.000000E+000	1073	0.000000E+000
X2	0	0.000000E+000	1254	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD2

Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	39	0.000000E+000
S11	0	0.000000E+000	0	0.000000E+000
S10	0	0.000000E+000	138	0.000000E+000
S8	0	0.000000E+000	4	0.000000E+000
S7	0	7.103725E-004	39	1.823289E+001
S31	0	0.000000E+000	1073	0.000000E+000
S2	0	0.000000E+000	1254	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	1255	0.000000E+000

Segment: SWITCH.NOD2

Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	181	0.000000E+000	1

Segment: SWITCH.NOD2

Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 0.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000 Sample size: 0

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	0	0.000	0.000
4	3.000000E+000	0	0.000	0.000
5	4.000000E+000	0	0.000	0.000
6	5.000000E+000	0	0.000	0.000
7	6.000000E+000	0	0.000	0.000

Segment: SWITCH.NOD3

Simulation time: 1.001000E+006 ms

Transi-tion	State	Utilization	Firings #	Mean firing time
T1000	0	1.804705E-003	114	1.584658E+001
T11	0	0.000000E+000	1	0.000000E+000
T31	0	0.000000E+000	2781	0.000000E+000
X2	0	0.000000E+000	3008	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD3
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	114	0.000000E+000
S11	0	0.000000E+000	1	0.000000E+000
S10	0	0.000000E+000	112	0.000000E+000
S8	0	0.000000E+000	0	0.000000E+000
S7	0	1.804705E-003	114	1.584658E+001
S31	0	0.000000E+000	2781	0.000000E+000
S2	0	0.000000E+000	3008	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	3009	0.000000E+000

Segment: SWITCH.NOD3
Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	227	0.000000E+000	1

Segment: SWITCH.NOD3
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 5.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 5.000000E+000 Sample size: 1

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	0	0.000	0.000
4	3.000000E+000	0	0.000	0.000
5	4.000000E+000	0	0.000	0.000
6	5.000000E+000	1	100.000	100.000
7	6.000000E+000	0	0.000	100.000

Segment: SWITCH.NOD4
Simulation time: 1.001000E+006 ms

Transi-tion	State	Utilization	Firings #	Mean firing time
T1000	0	8.253670E-004	61	1.354414E+001
T11	0	0.000000E+000	0	0.000000E+000
T31	0	0.000000E+000	1666	0.000000E+000
X2	0	0.000000E+000	1758	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD4
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	61	0.000000E+000
S11	0	0.000000E+000	0	0.000000E+000
S10	0	0.000000E+000	21	0.000000E+000
S8	0	0.000000E+000	10	0.000000E+000
S7	0	8.253670E-004	61	1.354414E+001
S31	0	0.000000E+000	1666	0.000000E+000
S2	0	0.000000E+000	1758	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	1759	0.000000E+000

Segment: SWITCH.NOD4
Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	92	0.000000E+000	1

Segment: SWITCH.NOD4
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 0.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000 Sample size: 0

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	0	0.000	0.000
4	3.000000E+000	0	0.000	0.000
5	4.000000E+000	0	0.000	0.000
6	5.000000E+000	0	0.000	0.000
7	6.000000E+000	0	0.000	0.000

Segment: SWITCH.NOD5
Simulation time: 1.001000E+006 ms

Transi-tion	State	Utilization	Firings #	Mean firing time
T1000	0	1.728771E-003	112	1.545089E+001
T11	0	0.000000E+000	1	0.000000E+000
T31	0	0.000000E+000	3487	0.000000E+000
X2	0	0.000000E+000	3707	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD5
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	112	0.000000E+000
S11	0	0.000000E+000	1	0.000000E+000
S10	0	0.000000E+000	98	0.000000E+000
S8	0	0.000000E+000	9	0.000000E+000
S7	0	1.728771E-003	112	1.545089E+001
S31	0	0.000000E+000	3487	0.000000E+000
S2	0	0.000000E+000	3707	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	3708	0.000000E+000

Segment: SWITCH.NOD5
Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	220	0.000000E+000	1

Segment: SWITCH.NOD5
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 4.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 4.000000E+000 Sample size: 1

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	0	0.000	0.000
4	3.000000E+000	0	0.000	0.000
5	4.000000E+000	1	100.000	100.000
6	5.000000E+000	0	0.000	100.000
7	6.000000E+000	0	0.000	100.000

Segment: SWITCH.NOD6
Simulation time: 1.001000E+006 ms

Transi-	State	Utilization	Firings	Mean firing

```
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  1.334383E-003 !       84!  1.590140E+001 !
!    T11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1502!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1611!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD6
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       84!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       18!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        4!  0.000000E+000 !
!     S7  !    0  !  1.334383E-003 !       84!  1.590140E+001 !
!    S31  !    0  !  0.000000E+000 !     1502!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1611!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1612!  0.000000E+000 !
-------------------------------------------------------------------

Segment: SWITCH.NOD6
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      109! 0.000000E+000!   1!
-------------------------------------------------------------------

Segment: SWITCH.NOD6
                      Simulation time: 1.001000E+006 ms


Table number:     1              Average value: 2.000000E+000
Argument name: Attribute HOPS     Stand. deviation: 1.732051E+000
Last arg. value: 1.000000E+000    Sample size:     3
-------------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         2 !  66.667  !   66.667   !
!     3    ! 2.000000E+000!         0 !   0.000  !   66.667   !
!     4    ! 3.000000E+000!         0 !   0.000  !   66.667   !
!     5    ! 4.000000E+000!         1 !  33.333  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------------

Segment: SWITCH.NOD7
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
```

```
-------------------------------------------------------------
!  T1000  !    0  !  9.462286E-004 !       61!  1.552746E+001 !
!    T11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2142!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2306!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD7
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       61!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      101!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!     S7  !    0  !  9.462286E-004 !       61!  1.552746E+001 !
!    S31  !    0  !  0.000000E+000 !     2142!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2306!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2307!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD7
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      164! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD7
                      Simulation time: 1.001000E+006 ms


Table number:     1              Average value: 1.500000E+000
Argument name: Attribute HOPS     Stand. deviation: 7.071068E-001
Last arg. value: 1.000000E+000    Sample size:     2
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         1 !  50.000  !   50.000   !
!     3    ! 2.000000E+000!         1 !  50.000  !  100.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD8
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
```

```
!  T1000  !    0  !  1.246293E-003 !       88!  1.417659E+001 !
!    T11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1633!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2027!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD8
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       88!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      299!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        6!  0.000000E+000 !
!     S7  !    0  !  1.246293E-003 !       88!  1.417659E+001 !
!    S31  !    0  !  0.000000E+000 !     1633!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2027!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2028!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD8
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      394! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD8
                      Simulation time: 1.001000E+006 ms


Table number:     1              Average value: 2.000000E+000
Argument name: Attribute HOPS     Stand. deviation: 0.000000E+000
Last arg. value: 2.000000E+000    Sample size:     1
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         1 ! 100.000  !  100.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD9
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  1.012256E-003 !       71!  1.427139E+001 !
```

```
!    T11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2535!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2885!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD9
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       71!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      259!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       20!  0.000000E+000 !
!     S7  !    0  !  1.012256E-003 !       71!  1.427139E+001 !
!    S31  !    0  !  0.000000E+000 !     2535!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2885!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2886!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD9
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      350! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD9
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 0.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000    Sample size:     0
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !    0.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !    0.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !    0.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !    0.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD10
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  1.852820E-003 !      115!  1.612759E+001 !
!    T11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
```

```
!    T31  !    0  !  0.000000E+000 !     1557!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1740!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD10
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !      115!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       60!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        6!  0.000000E+000 !
!     S7  !    0  !  1.852820E-003 !      115!  1.612759E+001 !
!    S31  !    0  !  0.000000E+000 !     1557!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1740!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1741!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD10
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      183! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD10
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 2.500000E+000
Argument name: Attribute HOPS      Stand. deviation: 7.071068E-001
Last arg. value: 2.000000E+000    Sample size:     2
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         1 !  50.000  !   50.000   !
!     4    ! 3.000000E+000!         1 !  50.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD11
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  5.776174E-004 !       41!  1.410232E+001 !
!    T11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !      763!  0.000000E+000 !
```

```
!     X2  !    0  !  0.000000E+000 !      896!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD11
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       41!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       89!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!     S7  !    0  !  5.776174E-004 !       41!  1.410232E+001 !
!    S31  !    0  !  0.000000E+000 !      763!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !      896!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !      897!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD11
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      133! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD11
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 0.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000    Sample size:     0
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !    0.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !    0.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !    0.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !    0.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD12
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  3.581864E-004 !       23!  1.558889E+001 !
!    T11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !      438!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !      469!  0.000000E+000 !
```

```
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD12
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       23!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !        4!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!     S7  !    0  !  3.581864E-004 !       23!  1.558889E+001 !
!    S31  !    0  !  0.000000E+000 !      438!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !      469!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !      470!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD12
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !       31! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD12
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 4.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 4.000000E+000    Sample size:     1
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !    0.000   !
!     5    ! 4.000000E+000!         1 ! 100.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD13
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  1.772424E-003 !      120!  1.478497E+001 !
!    T11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1777!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2142!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
```

```
------------------------------------------------------------

Segment: SWITCH.NOD13
                      Simulation time: 1.001000E+006 ms

------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !      120!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      232!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       11!  0.000000E+000 !
!     S7  !    0  !  1.772424E-003 !      120!  1.478497E+001 !
!    S31  !    0  !  0.000000E+000 !     1777!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2142!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2143!  0.000000E+000 !
------------------------------------------------------------

Segment: SWITCH.NOD13
                      Simulation time: 1.001000E+006 ms

------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      365! 0.000000E+000!   1!
------------------------------------------------------------

Segment: SWITCH.NOD13
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 5.500000E+000
Argument name: Attribute HOPS      Stand. deviation: 7.071068E-001
Last arg. value: 6.000000E+000    Sample size:     2
------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !    0.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !    0.000   !
!     6    ! 5.000000E+000!         1 !  50.000  !   50.000   !
!     7    ! 6.000000E+000!         1 !  50.000  !  100.000   !
------------------------------------------------------------
Average value in the last interval         6.000000E+000

Segment: SWITCH.NOD14
                      Simulation time: 1.001000E+006 ms

------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
------------------------------------------------------------
!  T1000  !    0  !  1.455875E-003 !       97!  1.502402E+001 !
!    T11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1326!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1593!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
```

```
-----------------------------------------------------------------

Segment: SWITCH.NOD14
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       97!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      169!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!     S7  !    0  !  1.455875E-003 !       97!  1.502402E+001 !
!    S31  !    0  !  0.000000E+000 !     1326!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1593!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1594!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD14
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      267! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD14
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 3.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 3.000000E+000    Sample size:     1
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         1 ! 100.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD15
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  2.971746E-004 !       20!  1.487359E+001 !
!    T11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !      896!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !      951!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------
```

Segment: SWITCH.NOD15
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	20	0.000000E+000
S11	0	0.000000E+000	0	0.000000E+000
S10	0	0.000000E+000	34	0.000000E+000
S8	0	0.000000E+000	1	0.000000E+000
S7	0	2.971746E-004	20	1.487359E+001
S31	0	0.000000E+000	896	0.000000E+000
S2	0	0.000000E+000	951	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	952	0.000000E+000

Segment: SWITCH.NOD15
Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	55	0.000000E+000	1

Segment: SWITCH.NOD15
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 0.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000 Sample size: 0

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	0	0.000	0.000
4	3.000000E+000	0	0.000	0.000
5	4.000000E+000	0	0.000	0.000
6	5.000000E+000	0	0.000	0.000
7	6.000000E+000	0	0.000	0.000

Segment: SWITCH.NOD16
Simulation time: 1.001000E+006 ms

Transi- tion	State	Utilization	Firings #	Mean firing time
T1000	0	5.685830E-004	34	1.673975E+001
T11	0	0.000000E+000	1	0.000000E+000
T31	0	0.000000E+000	1198	0.000000E+000
X2	0	0.000000E+000	1257	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD16
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	34	0.000000E+000
S11	0	0.000000E+000	1	0.000000E+000
S10	0	0.000000E+000	24	0.000000E+000
S8	0	0.000000E+000	0	0.000000E+000
S7	0	5.685830E-004	34	1.673975E+001
S31	0	0.000000E+000	1198	0.000000E+000
S2	0	0.000000E+000	1257	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	1258	0.000000E+000

Segment: SWITCH.NOD16
Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	59	0.000000E+000	1

Segment: SWITCH.NOD16
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 3.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 3.000000E+000 Sample size: 1

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	0	0.000	0.000
4	3.000000E+000	1	100.000	100.000
5	4.000000E+000	0	0.000	100.000
6	5.000000E+000	0	0.000	100.000
7	6.000000E+000	0	0.000	100.000

Segment: SWITCH.NOD17
Simulation time: 1.001000E+006 ms

Transi-tion	State	Utilization	Firings #	Mean firing time
T1000	0	2.936540E-003	183	1.606271E+001
T11	0	0.000000E+000	2	0.000000E+000
T31	0	0.000000E+000	2742	0.000000E+000
X2	0	0.000000E+000	3098	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD17

Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	183	0.000000E+000
S11	0	0.000000E+000	2	0.000000E+000
S10	0	0.000000E+000	171	0.000000E+000
S8	0	0.000000E+000	0	0.000000E+000
S7	0	2.936540E-003	183	1.606271E+001
S31	0	0.000000E+000	2742	0.000000E+000
S2	0	0.000000E+000	3098	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	3099	0.000000E+000

Segment: SWITCH.NOD17

Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	356	0.000000E+000	1

Segment: SWITCH.NOD17

Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 1.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 1.000000E+000 Sample size: 2

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	2	100.000	100.000
3	2.000000E+000	0	0.000	100.000
4	3.000000E+000	0	0.000	100.000
5	4.000000E+000	0	0.000	100.000
6	5.000000E+000	0	0.000	100.000
7	6.000000E+000	0	0.000	100.000

Segment: SWITCH.NOD18

Simulation time: 1.001000E+006 ms

Transi-tion	State	Utilization	Firings #	Mean firing time
T1000	0	1.098332E-003	76	1.446619E+001
T11	0	0.000000E+000	1	0.000000E+000
T31	0	0.000000E+000	1186	0.000000E+000
X2	0	0.000000E+000	1275	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD18

Simulation time: 1.001000E+006 ms

```
-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       76!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       12!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!     S7  !    0  !  1.098332E-003 !       76!  1.446619E+001 !
!    S31  !    0  !  0.000000E+000 !     1186!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1275!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1276!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD18
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !       89! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD18
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 2.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 2.000000E+000    Sample size:     1
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         1 ! 100.000  !  100.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD19
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  1.639955E-003 !      103!  1.593781E+001 !
!    T11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2270!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2478!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD19
                      Simulation time: 1.001000E+006 ms
```

```
-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !      103!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       91!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       12!  0.000000E+000 !
!     S7  !    0  !  1.639955E-003 !      103!  1.593781E+001 !
!    S31  !    0  !  0.000000E+000 !     2270!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2478!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2479!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD19
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      208! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD19
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 2.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 2.000000E+000    Sample size:     2
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         2 ! 100.000  !  100.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD20
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  2.622715E-003 !      167!  1.572058E+001 !
!    T11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2942!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     3268!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD20
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
```

```
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !      167!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      155!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!     S7  !    0  !  2.622715E-003 !      167!  1.572058E+001 !
!    S31  !    0  !  0.000000E+000 !     2942!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     3268!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     3269!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD20
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      326! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD20
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 1.666667E+000
Argument name: Attribute HOPS      Stand. deviation: 5.773503E-001
Last arg. value: 1.000000E+000    Sample size:     3
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         1 !  33.333  !   33.333   !
!     3    ! 2.000000E+000!         2 !  66.667  !  100.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD21
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  7.772042E-004 !       54!  1.440706E+001 !
!    T11  !    0  !  0.000000E+000 !        4!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2208!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2299!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD21
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
```

```
! place   !       !               ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       54!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        4!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       29!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        4!  0.000000E+000 !
!     S7  !    0  !  7.772042E-004 !       54!  1.440706E+001 !
!    S31  !    0  !  0.000000E+000 !     2208!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2299!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2300!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD21
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !       91! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD21
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 2.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 2.000000E+000
Last arg. value: 1.000000E+000    Sample size:     4
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         3 !  75.000  !   75.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !   75.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !   75.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !   75.000   !
!     6    ! 5.000000E+000!         1 !  25.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD22
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  1.770392E-003 !      116!  1.527726E+001 !
!    T11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1361!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1535!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD22
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
```

```
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !      116!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       54!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!     S7  !    0  !  1.770392E-003 !      116!  1.527726E+001 !
!    S31  !    0  !  0.000000E+000 !     1361!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1535!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1536!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD22
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      174! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD22
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 1.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 1.000000E+000    Sample size:     3
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         3 ! 100.000  !  100.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !  100.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD23
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  1.364016E-003 !       83!  1.645036E+001 !
!    T11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1773!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1950!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD23
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
```

```
!   S100  !    0  !  0.000000E+000 !       83!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       93!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!     S7  !    0  !  1.364016E-003 !       83!  1.645036E+001 !
!    S31  !    0  !  0.000000E+000 !     1773!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1950!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1951!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD23
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      177! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD23
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 0.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000    Sample size:     0
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !    0.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !    0.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !    0.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !    0.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD24
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  2.703510E-003 !      172!  1.573380E+001 !
!    T11  !    0  !  0.000000E+000 !        6!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2921!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     3146!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD24
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !      172!  0.000000E+000 !
```

```
!    S11  !    0  !  0.000000E+000 !        6!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       46!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!     S7  !    0  !  2.703510E-003 !      172!  1.573380E+001 !
!    S31  !    0  !  0.000000E+000 !     2921!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     3146!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     3147!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD24
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      225! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD24
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 1.333333E+000
Argument name: Attribute HOPS      Stand. deviation: 5.163978E-001
Last arg. value: 2.000000E+000    Sample size:     6
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         4 !  66.667  !   66.667   !
!     3    ! 2.000000E+000!         2 !  33.333  !  100.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD25
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  1.422870E-003 !      103!  1.382808E+001 !
!    T11  !    0  !  0.000000E+000 !        6!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2278!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2468!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD25
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !      103!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        6!  0.000000E+000 !
```

```
!    S10  !    0  !  0.000000E+000 !       81!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!     S7  !    0  !  1.422870E-003 !      103!  1.382808E+001 !
!    S31  !    0  !  0.000000E+000 !     2278!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2468!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2469!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD25
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      190! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD25
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 2.333333E+000
Argument name: Attribute HOPS      Stand. deviation: 1.505545E+000
Last arg. value: 3.000000E+000    Sample size:     6
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         2 !  33.333  !   33.333   !
!     3    ! 2.000000E+000!         2 !  33.333  !   66.667   !
!     4    ! 3.000000E+000!         1 !  16.667  !   83.333   !
!     5    ! 4.000000E+000!         0 !   0.000  !   83.333   !
!     6    ! 5.000000E+000!         1 !  16.667  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD26
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  1.518614E-003 !       98!  1.551156E+001 !
!    T11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1445!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1625!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD26
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       98!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       73!  0.000000E+000 !
```

```
!     S8  !    0  !  0.000000E+000 !        6!  0.000000E+000 !
!     S7  !    0  !  1.518614E-003 !       98!  1.551156E+001 !
!    S31  !    0  !  0.000000E+000 !     1445!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1625!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1626!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD26
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      180! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD26
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 1.666667E+000
Argument name: Attribute HOPS      Stand. deviation: 1.154701E+000
Last arg. value: 1.000000E+000    Sample size:     3
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         2 !  66.667  !   66.667   !
!     3    ! 2.000000E+000!         0 !   0.000  !   66.667   !
!     4    ! 3.000000E+000!         1 !  33.333  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD27
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  1.172434E-003 !       76!  1.544218E+001 !
!    T11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1234!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1474!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD27
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       76!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      147!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       15!  0.000000E+000 !
```

```
!     S7  !    0  !  1.172434E-003 !       76!  1.544218E+001 !
!    S31  !    0  !  0.000000E+000 !     1234!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1474!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1475!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD27
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      240! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD27
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 3.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 3.000000E+000    Sample size:     2
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         2 ! 100.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD28
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  5.446808E-004 !       34!  1.603604E+001 !
!    T11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2309!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2433!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD28
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       34!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       75!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       15!  0.000000E+000 !
!     S7  !    0  !  5.446808E-004 !       34!  1.603604E+001 !
```

```
!    S31  !    0  !  0.000000E+000 !     2309!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2433!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2434!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD28
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      124! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD28
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 0.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000    Sample size:     0
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !    0.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !    0.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !    0.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !    0.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD29
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  8.105358E-004 !       57!  1.423415E+001 !
!    T11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !      864!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !      953!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD29
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       57!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       29!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!     S7  !    0  !  8.105358E-004 !       57!  1.423415E+001 !
!    S31  !    0  !  0.000000E+000 !      864!  0.000000E+000 !
```

```
!     S2  !    0  !  0.000000E+000 !      953!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !      954!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD29
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !       89! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD29
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 2.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 2.000000E+000    Sample size:     2
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         2 ! 100.000  !  100.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD30
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  5.577474E-004 !       36!  1.550848E+001 !
!    T11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1811!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1971!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD30
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       36!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      112!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       10!  0.000000E+000 !
!     S7  !    0  !  5.577474E-004 !       36!  1.550848E+001 !
!    S31  !    0  !  0.000000E+000 !     1811!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1971!  0.000000E+000 !
```

```
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1972!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD30
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      160! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD30
                      Simulation time: 1.001000E+006 ms


Table number:     1              Average value: 5.000000E+000
Argument name: Attribute HOPS     Stand. deviation: 2.828427E+000
Last arg. value: 3.000000E+000    Sample size:     2
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         1 !  50.000  !   50.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !   50.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !   50.000   !
!     7    ! 6.000000E+000!         1 !  50.000  !  100.000   !
-----------------------------------------------------------------
Average value in the last interval         7.000000E+000

Segment: SWITCH.NOD31
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  8.316056E-004 !       54!  1.541550E+001 !
!    T11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !      536!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !      620!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD31
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       54!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       22!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        5!  0.000000E+000 !
!     S7  !    0  !  8.316056E-004 !       54!  1.541550E+001 !
!    S31  !    0  !  0.000000E+000 !      536!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !      620!  0.000000E+000 !
```

```
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !      621!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD31
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !       84! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD31
                      Simulation time: 1.001000E+006 ms


Table number:     1              Average value: 3.000000E+000
Argument name: Attribute HOPS     Stand. deviation: 0.000000E+000
Last arg. value: 3.000000E+000    Sample size:     3
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         3 ! 100.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD32
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    1  !  2.088429E-003 !      137!  1.525925E+001 !
!    T11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1758!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2197!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD32
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !      136!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      279!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       22!  0.000000E+000 !
!     S7  !    1  !  2.088429E-003 !      137!  1.525925E+001 !
!    S31  !    0  !  0.000000E+000 !     1758!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2197!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
```

```
!   S200  !    0  !  0.000000E+000 !     2198!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD32
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      439! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD32
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 2.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 2.000000E+000    Sample size:     1
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         1 ! 100.000  !  100.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD33
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  1.389269E-003 !       87!  1.598458E+001 !
!    T11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1660!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1874!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD33
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       87!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      111!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       14!  0.000000E+000 !
!     S7  !    0  !  1.389269E-003 !       87!  1.598458E+001 !
!    S31  !    0  !  0.000000E+000 !     1660!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1874!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1875!  0.000000E+000 !
```

```
-----------------------------------------------------------------

Segment: SWITCH.NOD33
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-----------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      214! 0.000000E+000!   1!
-----------------------------------------------------------------

Segment: SWITCH.NOD33
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 4.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 4.000000E+000    Sample size:     2
-----------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-----------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !    0.000   !
!     5    ! 4.000000E+000!         2 ! 100.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-----------------------------------------------------------------

Segment: SWITCH.NOD34
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-----------------------------------------------------------------
!  T1000  !    0  !  1.018227E-003 !       72!  1.415619E+001 !
!    T11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1490!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1602!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-----------------------------------------------------------------

Segment: SWITCH.NOD34
                      Simulation time: 1.001000E+006 ms

-----------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-----------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       72!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       37!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!     S7  !    0  !  1.018227E-003 !       72!  1.415619E+001 !
!    S31  !    0  !  0.000000E+000 !     1490!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1602!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1603!  0.000000E+000 !
-----------------------------------------------------------------
```

Segment: SWITCH.NOD34
Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	112	0.000000E+000	1

Segment: SWITCH.NOD34
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 2.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 2.000000E+000 Sample size: 3

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	3	100.000	100.000
4	3.000000E+000	0	0.000	100.000
5	4.000000E+000	0	0.000	100.000
6	5.000000E+000	0	0.000	100.000
7	6.000000E+000	0	0.000	100.000

Segment: SWITCH.NOD35
Simulation time: 1.001000E+006 ms

Transition	State	Utilization	Firings #	Mean firing time
T1000	0	1.015585E-003	66	1.540304E+001
T11	0	0.000000E+000	1	0.000000E+000
T31	0	0.000000E+000	609	0.000000E+000
X2	0	0.000000E+000	832	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD35
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	66	0.000000E+000
S11	0	0.000000E+000	1	0.000000E+000
S10	0	0.000000E+000	138	0.000000E+000
S8	0	0.000000E+000	18	0.000000E+000
S7	0	1.015585E-003	66	1.540304E+001
S31	0	0.000000E+000	609	0.000000E+000
S2	0	0.000000E+000	832	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	833	0.000000E+000

Segment: SWITCH.NOD35
Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	223	0.000000E+000	1

Segment: SWITCH.NOD35
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 4.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 4.000000E+000 Sample size: 1

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	0	0.000	0.000
4	3.000000E+000	0	0.000	0.000
5	4.000000E+000	1	100.000	100.000
6	5.000000E+000	0	0.000	100.000
7	6.000000E+000	0	0.000	100.000

Segment: SWITCH.NOD36
Simulation time: 1.001000E+006 ms

Transition	State	Utilization	Firings #	Mean firing time
T1000	0	1.400902E-003	90	1.558114E+001
T11	0	0.000000E+000	0	0.000000E+000
T31	0	0.000000E+000	865	0.000000E+000
X2	0	0.000000E+000	1080	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD36
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	90	0.000000E+000
S11	0	0.000000E+000	0	0.000000E+000
S10	0	0.000000E+000	122	0.000000E+000
S8	0	0.000000E+000	3	0.000000E+000
S7	0	1.400902E-003	90	1.558114E+001
S31	0	0.000000E+000	865	0.000000E+000
S2	0	0.000000E+000	1080	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	1081	0.000000E+000

Segment: SWITCH.NOD36

Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	215	0.000000E+000	1

Segment: SWITCH.NOD36
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 0.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000 Sample size: 0

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	0	0.000	0.000
4	3.000000E+000	0	0.000	0.000
5	4.000000E+000	0	0.000	0.000
6	5.000000E+000	0	0.000	0.000
7	6.000000E+000	0	0.000	0.000

Segment: SWITCH.NOD37
Simulation time: 1.001000E+006 ms

Transi-tion	State	Utilization	Firings #	Mean firing time
T1000	0	1.755958E-003	109	1.612582E+001
T11	0	0.000000E+000	1	0.000000E+000
T31	0	0.000000E+000	1742	0.000000E+000
X2	0	0.000000E+000	2007	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD37
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	109	0.000000E+000
S11	0	0.000000E+000	1	0.000000E+000
S10	0	0.000000E+000	146	0.000000E+000
S8	0	0.000000E+000	9	0.000000E+000
S7	0	1.755958E-003	109	1.612582E+001
S31	0	0.000000E+000	1742	0.000000E+000
S2	0	0.000000E+000	2007	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	2008	0.000000E+000

Segment: SWITCH.NOD37
Simulation time: 1.001000E+006 ms

```
-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      265! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD37
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 3.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 3.000000E+000    Sample size:     1
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         1 ! 100.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD38
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  7.445785E-004 !       50!  1.490646E+001 !
!    T11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1074!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1154!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD38
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       50!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       29!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!     S7  !    0  !  7.445785E-004 !       50!  1.490646E+001 !
!    S31  !    0  !  0.000000E+000 !     1074!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1154!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1155!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD38
                      Simulation time: 1.001000E+006 ms
```

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	80	0.000000E+000	1

Segment: SWITCH.NOD38
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 1.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 1.000000E+000 Sample size: 1

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	1	100.000	100.000
3	2.000000E+000	0	0.000	100.000
4	3.000000E+000	0	0.000	100.000
5	4.000000E+000	0	0.000	100.000
6	5.000000E+000	0	0.000	100.000
7	6.000000E+000	0	0.000	100.000

Segment: SWITCH.NOD39
Simulation time: 1.001000E+006 ms

Transi-tion	State	Utilization	Firings #	Mean firing time
T1000	0	1.524394E-003	97	1.573111E+001
T11	0	0.000000E+000	0	0.000000E+000
T31	0	0.000000E+000	1679	0.000000E+000
X2	0	0.000000E+000	1823	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD39
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	97	0.000000E+000
S11	0	0.000000E+000	0	0.000000E+000
S10	0	0.000000E+000	40	0.000000E+000
S8	0	0.000000E+000	7	0.000000E+000
S7	0	1.524394E-003	97	1.573111E+001
S31	0	0.000000E+000	1679	0.000000E+000
S2	0	0.000000E+000	1823	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	1824	0.000000E+000

Segment: SWITCH.NOD39
Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	144	0.000000E+000	1

Segment: SWITCH.NOD39
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 0.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000 Sample size: 0

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	0	0.000	0.000
4	3.000000E+000	0	0.000	0.000
5	4.000000E+000	0	0.000	0.000
6	5.000000E+000	0	0.000	0.000
7	6.000000E+000	0	0.000	0.000

Segment: SWITCH.NOD40
Simulation time: 1.001000E+006 ms

Transi-tion	State	Utilization	Firings #	Mean firing time
T1000	0	1.850240E-003	117	1.582983E+001
T11	0	0.000000E+000	4	0.000000E+000
T31	0	0.000000E+000	3750	0.000000E+000
X2	0	0.000000E+000	3956	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD40
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	117	0.000000E+000
S11	0	0.000000E+000	4	0.000000E+000
S10	0	0.000000E+000	77	0.000000E+000
S8	0	0.000000E+000	8	0.000000E+000
S7	0	1.850240E-003	117	1.582983E+001
S31	0	0.000000E+000	3750	0.000000E+000
S2	0	0.000000E+000	3956	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	3957	0.000000E+000

Segment: SWITCH.NOD40
Simulation time: 1.001000E+006 ms

Queue	State	Mean	Tokens	Mean token	Max.

```
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      206! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD40
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 3.750000E+000
Argument name: Attribute HOPS      Stand. deviation: 2.217356E+000
Last arg. value: 1.000000E+000    Sample size:     4
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         1 !  25.000  !   25.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !   25.000   !
!     4    ! 3.000000E+000!         1 !  25.000  !   50.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !   50.000   !
!     6    ! 5.000000E+000!         1 !  25.000  !   75.000   !
!     7    ! 6.000000E+000!         1 !  25.000  !  100.000   !
-------------------------------------------------------------
Average value in the last interval         6.000000E+000

Segment: SWITCH.NOD41
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  1.508946E-003 !       97!  1.557170E+001 !
!    T11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1698!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     1988!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD41
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       97!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      178!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       13!  0.000000E+000 !
!     S7  !    0  !  1.508946E-003 !       97!  1.557170E+001 !
!    S31  !    0  !  0.000000E+000 !     1698!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     1988!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     1989!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD41
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
```

```
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      290! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD41
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 4.500000E+000
Argument name: Attribute HOPS      Stand. deviation: 2.121320E+000
Last arg. value: 6.000000E+000    Sample size:     2
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         1 !  50.000  !   50.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !   50.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !   50.000   !
!     7    ! 6.000000E+000!         1 !  50.000  !  100.000   !
-------------------------------------------------------------
Average value in the last interval         6.000000E+000

Segment: SWITCH.NOD42
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  1.728044E-003 !      115!  1.504149E+001 !
!    T11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     3629!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     3977!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD42
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !      115!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        2!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      210!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       21!  0.000000E+000 !
!     S7  !    0  !  1.728044E-003 !      115!  1.504149E+001 !
!    S31  !    0  !  0.000000E+000 !     3629!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     3977!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     3978!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD42
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
```

```
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      348! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD42
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 4.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 4.000000E+000    Sample size:     2
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !    0.000   !
!     5    ! 4.000000E+000!         2 ! 100.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD43
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  1.758143E-003 !      115!  1.530349E+001 !
!    T11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2023!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2317!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD43
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !      115!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      164!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       14!  0.000000E+000 !
!     S7  !    0  !  1.758143E-003 !      115!  1.530349E+001 !
!    S31  !    0  !  0.000000E+000 !     2023!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2317!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2318!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD43
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
```

```
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      294! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD43
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 3.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 3.000000E+000    Sample size:     1
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         1 ! 100.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD44
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  1.146618E-003 !       78!  1.471493E+001 !
!    T11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2455!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2623!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD44
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       78!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       88!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!     S7  !    0  !  1.146618E-003 !       78!  1.471493E+001 !
!    S31  !    0  !  0.000000E+000 !     2455!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2623!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2624!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD44
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
```

```
!     Q1  !   0 ! 0.000000E+000 !      168! 0.000000E+000!   1!
-------------------------------------------------------------

Segment: SWITCH.NOD44
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 2.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 2.000000E+000    Sample size:     1
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         1 ! 100.000  !  100.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD45
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------
!  T1000  !    0  !  1.246131E-003 !       77!  1.619970E+001 !
!    T11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2459!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2669!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD45
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       77!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      124!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        9!  0.000000E+000 !
!     S7  !    0  !  1.246131E-003 !       77!  1.619970E+001 !
!    S31  !    0  !  0.000000E+000 !     2459!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2669!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2670!  0.000000E+000 !
-------------------------------------------------------------

Segment: SWITCH.NOD45
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      210! 0.000000E+000!   1!
```

```
------------------------------------------------------------

Segment: SWITCH.NOD45
                      Simulation time: 1.001000E+006 ms


Table number:     1               Average value: 0.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000    Sample size:     0
------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         0 !   0.000  !    0.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !    0.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !    0.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !    0.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !    0.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !    0.000   !
------------------------------------------------------------

Segment: SWITCH.NOD46
                      Simulation time: 1.001000E+006 ms

------------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
------------------------------------------------------------------
!  T1000  !    0  !  9.676769E-004 !       61!  1.587942E+001 !
!    T11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     2168!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2341!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
------------------------------------------------------------------

Segment: SWITCH.NOD46
                      Simulation time: 1.001000E+006 ms

------------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
------------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       61!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !      100!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !       12!  0.000000E+000 !
!     S7  !    0  !  9.676769E-004 !       61!  1.587942E+001 !
!    S31  !    0  !  0.000000E+000 !     2168!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2341!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2342!  0.000000E+000 !
------------------------------------------------------------------

Segment: SWITCH.NOD46
                      Simulation time: 1.001000E+006 ms

------------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
------------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      173! 0.000000E+000!   1!
------------------------------------------------------------------
```

Segment: SWITCH.NOD46
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 0.000000E+000
Argument name: Attribute HOPS Stand. deviation: 0.000000E+000
Last arg. value: 0.000000E+000 Sample size: 0

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	0	0.000	0.000
4	3.000000E+000	0	0.000	0.000
5	4.000000E+000	0	0.000	0.000
6	5.000000E+000	0	0.000	0.000
7	6.000000E+000	0	0.000	0.000

Segment: SWITCH.NOD47
Simulation time: 1.001000E+006 ms

Transition	State	Utilization	Firings #	Mean firing time
T1000	0	1.409759E-003	87	1.622033E+001
T11	0	0.000000E+000	2	0.000000E+000
T31	0	0.000000E+000	2515	0.000000E+000
X2	0	0.000000E+000	2672	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD47
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	87	0.000000E+000
S11	0	0.000000E+000	2	0.000000E+000
S10	0	0.000000E+000	68	0.000000E+000
S8	0	0.000000E+000	0	0.000000E+000
S7	0	1.409759E-003	87	1.622033E+001
S31	0	0.000000E+000	2515	0.000000E+000
S2	0	0.000000E+000	2672	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	2673	0.000000E+000

Segment: SWITCH.NOD47
Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	157	0.000000E+000	1

Segment: SWITCH.NOD47
Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 2.500000E+000
Argument name: Attribute HOPS Stand. deviation: 7.071068E-001
Last arg. value: 2.000000E+000 Sample size: 2

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	0	0.000	0.000
3	2.000000E+000	1	50.000	50.000
4	3.000000E+000	1	50.000	100.000
5	4.000000E+000	0	0.000	100.000
6	5.000000E+000	0	0.000	100.000
7	6.000000E+000	0	0.000	100.000

Segment: SWITCH.NOD48
Simulation time: 1.001000E+006 ms

Transition	State	Utilization	Firings #	Mean firing time
T1000	0	1.853673E-003	127	1.461045E+001
T11	0	0.000000E+000	5	0.000000E+000
T31	0	0.000000E+000	2263	0.000000E+000
X2	0	0.000000E+000	2624	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD48
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	127	0.000000E+000
S11	0	0.000000E+000	5	0.000000E+000
S10	0	0.000000E+000	213	0.000000E+000
S8	0	0.000000E+000	16	0.000000E+000
S7	0	1.853673E-003	127	1.461045E+001
S31	0	0.000000E+000	2263	0.000000E+000
S2	0	0.000000E+000	2624	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	2625	0.000000E+000

Segment: SWITCH.NOD48
Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	361	0.000000E+000	1

Segment: SWITCH.NOD48

Simulation time: 1.001000E+006 ms

Table number: 1 Average value: 2.200000E+000
Argument name: Attribute HOPS Stand. deviation: 1.095445E+000
Last arg. value: 3.000000E+000 Sample size: 5

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	2	40.000	40.000
3	2.000000E+000	0	0.000	40.000
4	3.000000E+000	3	60.000	100.000
5	4.000000E+000	0	0.000	100.000
6	5.000000E+000	0	0.000	100.000
7	6.000000E+000	0	0.000	100.000

Segment: SWITCH.NOD49
Simulation time: 1.001000E+006 ms

Transi-tion	State	Utilization	Firings #	Mean firing time
T1000	0	1.332632E-003	82	1.626786E+001
T11	0	0.000000E+000	1	0.000000E+000
T31	0	0.000000E+000	1883	0.000000E+000
X2	0	0.000000E+000	1990	0.000000E+000
T999	0	0.000000E+000	0	0.000000E+000

Segment: SWITCH.NOD49
Simulation time: 1.001000E+006 ms

Single place	State	Utilization	Tokens passed	Mean token time
S100	0	0.000000E+000	82	0.000000E+000
S11	0	0.000000E+000	1	0.000000E+000
S10	0	0.000000E+000	16	0.000000E+000
S8	0	0.000000E+000	8	0.000000E+000
S7	0	1.332632E-003	82	1.626786E+001
S31	0	0.000000E+000	1883	0.000000E+000
S2	0	0.000000E+000	1990	0.000000E+000
S1	0	0.000000E+000	1	0.000000E+000
S200	0	0.000000E+000	1991	0.000000E+000

Segment: SWITCH.NOD49
Simulation time: 1.001000E+006 ms

Queue place	State	Mean length	Tokens passed	Mean token time	Max. len.
Q1	0	0.000000E+000	107	0.000000E+000	1

Segment: SWITCH.NOD49
Simulation time: 1.001000E+006 ms

```
Table number:     1               Average value: 1.000000E+000
Argument name: Attribute HOPS      Stand. deviation: 0.000000E+000
Last arg. value: 1.000000E+000    Sample size:     1
-------------------------------------------------------------
! Interval !High boundary ! Interval  ! Relative ! Cumulative !
!    #     ! of  interval !  counter  ! freq., % ! freq., %   !
-------------------------------------------------------------
!     1    ! 0.000000E+000!         0 !   0.000  !    0.000   !
!     2    ! 1.000000E+000!         1 ! 100.000  !  100.000   !
!     3    ! 2.000000E+000!         0 !   0.000  !  100.000   !
!     4    ! 3.000000E+000!         0 !   0.000  !  100.000   !
!     5    ! 4.000000E+000!         0 !   0.000  !  100.000   !
!     6    ! 5.000000E+000!         0 !   0.000  !  100.000   !
!     7    ! 6.000000E+000!         0 !   0.000  !  100.000   !
-------------------------------------------------------------

Segment: SWITCH.NOD50
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------------
! Transi- ! State !   Utilization  ! Firings !   Mean firing  !
! tion    !       !                !    #    !      time      !
-------------------------------------------------------------------
!  T1000  !    0  !  7.794456E-004 !       58!  1.345216E+001 !
!    T11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    T31  !    0  !  0.000000E+000 !     1946!  0.000000E+000 !
!     X2  !    0  !  0.000000E+000 !     2096!  0.000000E+000 !
!   T999  !    0  !  0.000000E+000 !        0!  0.000000E+000 !
-------------------------------------------------------------------

Segment: SWITCH.NOD50
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------------
! Single  ! State !  Utilization   ! Tokens  !   Mean token   !
! place   !       !                ! passed  !   time         !
-------------------------------------------------------------------
!   S100  !    0  !  0.000000E+000 !       58!  0.000000E+000 !
!    S11  !    0  !  0.000000E+000 !        3!  0.000000E+000 !
!    S10  !    0  !  0.000000E+000 !       88!  0.000000E+000 !
!     S8  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!     S7  !    0  !  7.794456E-004 !       58!  1.345216E+001 !
!    S31  !    0  !  0.000000E+000 !     1946!  0.000000E+000 !
!     S2  !    0  !  0.000000E+000 !     2096!  0.000000E+000 !
!     S1  !    0  !  0.000000E+000 !        1!  0.000000E+000 !
!   S200  !    0  !  0.000000E+000 !     2097!  0.000000E+000 !
-------------------------------------------------------------------

Segment: SWITCH.NOD50
                      Simulation time: 1.001000E+006 ms

-------------------------------------------------------------------
!  Queue  !State!     Mean      !  Tokens !  Mean token  !Max.!
!  place  !     !    length     !  passed !     time     !len.!
-------------------------------------------------------------------
!     Q1  !   0 ! 0.000000E+000 !      150! 0.000000E+000!   1!
-------------------------------------------------------------------

Segment: SWITCH.NOD50
                      Simulation time: 1.001000E+006 ms
```

Table number: 1 Average value: 1.666667E+000
Argument name: Attribute HOPS Stand. deviation: 5.773503E-001
Last arg. value: 1.000000E+000 Sample size: 3

Interval #	High boundary of interval	Interval counter	Relative freq., %	Cumulative freq., %
1	0.000000E+000	0	0.000	0.000
2	1.000000E+000	1	33.333	33.333
3	2.000000E+000	2	66.667	100.000
4	3.000000E+000	0	0.000	100.000
5	4.000000E+000	0	0.000	100.000
6	5.000000E+000	0	0.000	100.000
7	6.000000E+000	0	0.000	100.000