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Performance Evaluation of Mobile Ad-Hoc Network Based on DSR Routing Protocol

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Abstract: In this paper, a brief review of most conventional routing protocols for mobile Ad-Hoc networks has been conducted, moreover Dynamic Source Routing (DSR) protocol has been discussed with more details. The focuses on both route discovery and route maintaining phases as the main part of DSR protocol have been done and simulated in this paper. Random movement pattern for mobility of nodes have been assumed with random walk model. Also, negative exponential random model for time duration of a call. In addition with letting poisson distribution of a call demand, are assumed as the main problem definitions. Two main performance indices namely, call blocking and forced termination probabilities as constraints have been introduced. The above two indices for different loads and moving velocities have been simulated. In order to show the effects of Ad- Hoc routing protocol on service quality. Two type of direct and indirect path servicing have been studied. Results shows that a multi loop path introduces lower blocking and forced termination rates.

Keywords*: Ad Hoc, Blocking Probability, Forced Termination Probability, MANET, Wireless Network*

ارزیابی عملکرد شبکه‌های موبایل Ad- Hoc مبتنی بر پروتکل مسیریابی DSR

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چکیده: در این مقاله مرور کوتاهی بر پروتکل‌های مسیریابی متداول برای شبکه‌های موبایل Ad-Hoc معرفی شده است و پروتکل مسیریابی DSR با جزئیات بیشتری شرح داده شده است. عنایت بیشتر بر روی موضوع مسیریابی و فازهای تأمین مسیر به عنوان اصلی‌ترین بخش‌های DSR قرار گرفته که شبیه‌سازی شده است. تعریف مسئله با خصوصیات الگوی حرکت تصادفی برای حرکتها، مدل نمایی منفی برای زمان مکالمه و توزیع پواسون برای تقاضای زمان مکالمه در نظر گرفته شده که همراه با دو شاخص کارآیی اصلی احتمال عدم امکان تماس و قطع شدن اجباری تماس معرفی شده است. این دو شاخص کارآیی به‌ازاء بارهای ترافیکی و سرعت‌های متفاوت شبیه سازی و استخراج شده‌اند. به منظور نمایش اثر پروتکل مسیریابی بر کیفیت سرویس، دو روش مستقیم و غیر مستقیم مسیریابی شبیه سازی شده‌اند، نتایج شبیه‌سازی نشانگر کاهش عدم امکان تماس و قطع شدن اجباری تماس با استفاده از روش یافتن مسیر چندگانه می‌باشد.

کلمات کلیدی: احتمال عدم امکان تماس، احتمال قطع اجباری تماس، شبکه‌های موبایل Ad-Hoc، شبکه‌های بی‌سیم MANET.

1. Introduction

Progress in radio communications, multiple access schemes, and coding algorithms brought the means for the implementation of mobile communications for personal users. So, the new era of Personal Communication Services (PCS) has started. The concept of cellular structure has been included in order to achieve higher spectral efficiency by reusing a same frequency band in a cell far enough from another one using the same frequency band.

In a cellular network, a service coverage area is divided into smaller areas of hexagonal shape, referred to as cells. Each cell is served by a fixed base station. A mobile station communicates with another station, either mobile or land, via a base station. A mobile can not communicate with another mobile station directly. To make a call from a mobile station, the mobile station first needs to make a request using a reverse control channel of the current cell.

In spite of all advantages of cellular networks, it has some disadvantages as follow:

- It can not be used at remote construction sites;
- Building infrastructure becomes uneconomical when traffic demand and the forecasted revenue are too low;
- Inefficiency in emergency conditions (torrential, earthquake, etc);
- It is not absolutely a mobile network [1, 2, 3].

These limitations forced us to search about a new idea that helps us in other situations. A mobile Ad-Hoc network is an answer to solve these problems. Routing, scheduling and power control are the main issues in these networks [4].

Main goal of this investigation is a brief review of Mobile Ad-Hoc networks and simulating an Ad-Hoc network. Evaluating the performance metrics regarding different traffics and mobile velocities is the output of this research.

This paper is structured as follows. Section 2 has a brief review on mobile Ad-Hoc networks. In section 3, routing protocols are presented. DSR protocol, DSR route discovery and its route maintenance can be found in section 4. Simulation assumptions like as movement pattern, call request model and call duration time distribution and considered inputs, and performance metrics are discussed in section 5. Section 6 presents simulation results. Section 7 concludes this investigation.

2. Mobile Ad- Hoc Network

A Mobile Ad-hoc NETwork (MANET) is one that comes together as needed, not necessarily with any support from the existing Internet infrastructure or any other kind of fixed stations. We can formalize this statement by defining an Ad-Hoc network as an autonomous system of mobile hosts (also serving as routers) connected by wireless links, the union of which forms a communication network modeled in the form of an arbitrary graph. This is in contrast to the well-known single hop cellular network model that supports the needs of wireless communication by installing base stations as access point in these cellular networks, communications between two mobile nodes completely rely on the wired backbone and

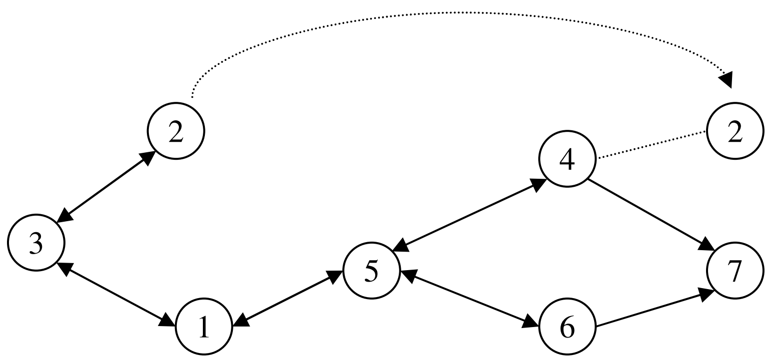

Fig. 1. A mobile Ad-Hoc topology

the fixed base stations. In a MANET, no such infrastructure exists and the network topology may dynamically change in an unpredictable manner since nodes are free to move. As for the mode of operation, Ad-Hoc networks are basically peer-to-peer multi-hop mobile wireless networks where information packets are transmitted in a store-and-forward manner from a source to an arbitrary destination, via intermediate nodes as shown in Fig. 1. As the nodes move, the resulting change in network topology must be made known to the other nodes so that outdated topology information can be updated or removed. For example, as NODE2 in Fig. 1 changes its point of attachment from NODE3 to NODE4 other nodes part of the network should use this new route to forward packets to NODE2 [5, 6].

In the case that all nodes are close-by within radio range, there are no routing issues to be addressed. In real situations, the power needed to obtain complete connectivity may be, at least, infeasible, not to mention issues such as battery life.

The issue of symmetric and asymmetric links is one among the several challenges encountered in a MANET. Another important issue is that different nodes often have different mobility patterns. Some nodes are highly mobile, while others are primarily stationary. It is difficult to predict a node's movement and pattern of movement [3, 4, 5].

3. Routing Protocols

Table-Driven routing protocols attempt to maintain consistent, up-to-date routing information from each node to every other node in the network. These protocols require each node to maintain one or more tables to store routing information, and they respond to changes in network topology by propagating updates throughout the network in order to maintain a consistent network view. The areas in which they differ are the number of necessary routing-related tables and the methods by which changes in network structure are broadcasted.

Numerous protocols have been developed for Ad Hoc mobile networks to deal with the typical limitations of these networks, which include high power consumption, low bandwidth, and high error rates. As shown in Fig. 2, routing protocols may generally be categorized as two types:

- Table-Driven
- Source-Initiated (Demand-Driven)

Solid lines in this figure represent direct descendants, while dotted lines depict logical descendants. Despite being designed for the same type of underlying network, the characteristics of each of these protocols are quite distinct.

A different approach from Table-Driven routing is Source-Initiated On-Demand routing. This type of routing creates routes only when desired by the source node. When a node requires a route to a destination, it initiates a route discovery process within the network. This process is completed once a route is found or all possible route permutations have been examined. Once a route has been established, it is maintained by a route maintenance procedure until either the destination becomes inaccessible along every path from the source or until the route is no longer desired [3, 4]. Section 4 focused on DSR protocol which simulated in this investigation

4. DSR Routing Protocol

The DSR protocol is a Source-Initiated routing composed of two mechanisms that work together to allow the discovery and maintenance of source routes in the Ad-Hoc network.

Route Discovery and Route Maintenance techniques operate entirely *on demand*. In particular, unlike other protocols, DSR requires *no* periodic packets of *any kind* at *any level* within the network. For example, DSR does not use any periodic routing advertisement, link status sensing, or neighbor detection packets, and does not rely on these functions from any underlying protocols in the network. This entirely on-demand behavior and lack of periodic activity allows the number of overhead packets caused by DSR to scale all the way down to *zero*, when all nodes are approximately stationary with respect to each other and all routes needed for current communication have already been discovered. As nodes begin to move more or as communication patterns change, the routing packet overhead of DSR *automatically* scales to only that needed to track the routes currently in use.

DSR also supports internetworking between different types of wireless networks, allowing a source route to be composed of hops over a combination of any types of networks available [5, 6].

4.1 Basic DSR Route Discovery

When some node **S** originates a new packet destined to some other node **D**, it places in the header of the packet a *source route* giving the sequence of hops that the packet should follow on its way to **D**. Normally, **S** will obtain a suitable source route by searching its *Route Cache* of routes previously learned, but if no route is found in its cache, it will initiate the Route Discovery protocol to dynamically find a new route to **D**. In this case, we call **S** the *initiator* and **D** the *target.*

For example, Fig. 3 illustrates an example of Route Discovery, in which a node **A** is attempting to discover a route to node **E**.

To initiate the Route Discovery, **A** transmits a ROUTE REQUEST message as a single local broadcast packet, which is received by (approximately) all nodes currently within wireless transmission range of **A**. Each ROUTE REQ-UEST message identifies the initiator and target of the Route Discovery, and also contains a unique *request id*, determined by the initiator of the REQUEST. Each ROUTE REQUEST also contains a record listing the address of each intermediate node through which this particular copy of the ROUTE REQUEST message has been forwarded. This route record is initialized to an empty list by the initiator of the Route Discovery.

When another node receives a ROUTE REQUEST, if it is the target of the Route Discovery, it returns a ROUTE REPLY message to the initiator of the Route Discovery, giving a copy of the accumulated route record from the ROUTE REQUEST; when the initiator receives this ROUTE REPLY, it caches this route in its Route Cache for use in sending subsequent packets to this destination. Otherwise, if this node receiving the ROUTE REQUEST has recently seen another ROUTE REQUEST message from this initiator bearing this same request id, or if it finds that its own address is already listed in the route-record in the ROUTE REQUEST message, it discards the REQUEST. Otherwise, this node appends its own address to the route record in the ROUTE REQUEST message and propagates it by transmitting it as a local broadcast packet. In returning the ROUTE REPLY to the initiator of the Route Discovery, such as node **E** replying back to **A** in Fig. 3, node **E** will typically examine its own Route Cache for a route back to **A**, and if found, will use it for the source route for delivery of the packet containing the ROUTE REPLY. Otherwise, **E** may perform its own Route Discovery for target node **A**, but to avoid possible infinite recursion of Route Discoveries, it must piggyback this ROUTE REPLY on its own ROUTE REQUEST message for **A** [7, 8, 9].

4.2. Basic DSR Route Maintenance

When originating or forwarding a packet using a source route, each node transmitting the packet is responsible for confirming that the packet has been received by the next hop along the source route; the packet is retransmitted (up to a maximum number of attempts) until this confirmation of receipt is received. For example, in the situation illustrated in Fig. 4, node **A** has originated a packet for **E** using a source route through intermediate nodes **B**, **C**, and **D**. In this case, node **A** is responsible for receipt of the packet at **B**, node **B** is responsible for receipt at **C**, node **C** is responsible for receipt at **D**, and node **D** is responsible for receipt finally at the destination **E**. This confirmation of receipt in many cases may be provided at no cost to DSR, either as an existing standard part of the MAC protocol in use (such as the link-level acknowledgement frame defined by IEEE 802.11), or by a *passive acknowledgement* [2, 3, 4, 5, 9].

5. Simulation Assumptions & Criteria

Research in Ad-Hoc network often involves simulators since management and operation a large number of nodes is expensive. At first, we simulate a wireless network that its nodes communicate together without any fixed station and then apply DSR protocol on the network and compare results and analyze the effect of Ad-Hoc method.

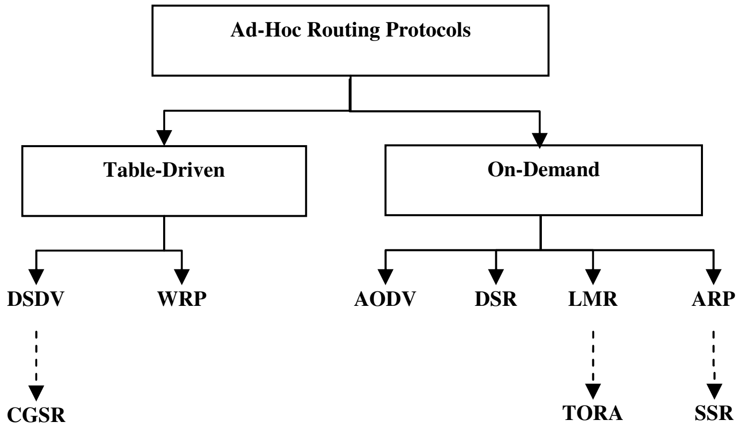

Fig. 2. Ad-Hoc routing protocols

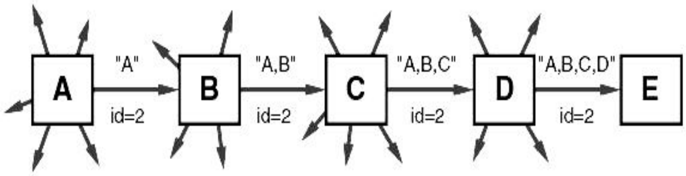

Fig. 3. Route discovery example (Node A is the initiator and node E is the target)

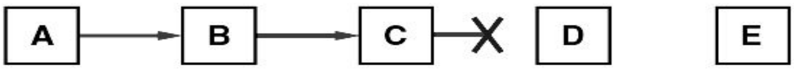

Fig. 4. Route maintenance example
(Node C is unable to forward a packet from node A to node E over its link to next hop through D)

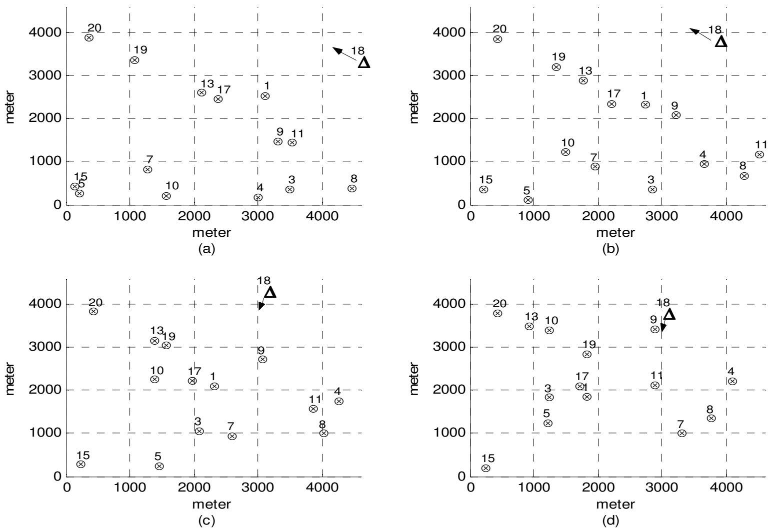

Fig. 5. Movement pattern of nodes in four different times

MATLAB package has been used to simulate a network. In this investigation a virtual environment of 3400 m×3400 m for 3600s of simulation time considering 20 nodes have been simulated. Each node can send its information with maximum power up to 15 dBm. In the same way, other node will receive the information if minimum received power is more than -98 dBm. The transmission radius of a node is about 1200m and a node serve as router or host not both of them.

5.1. Movement Pattern

In the simulation, the nodes move according to the *Random Walk* model. At the start of the simulation, each node waits for a pause time, then randomly selects and moves towards a destination with a random velocity in an interval between zero and some maximum speed. On reaching this destination it pauses again and repeats the above procedure till the end of the simulation. Fig. 5 shows movement pattern of different times. Each node change its direction when hits to boundary of simulated structure. Also each node moves with a constant velocity which has a great effect on the network response [5, 7].

5.2. Call Request Model

The number of call requests is in accordance with Poisson distribution (equation 1).

$$f_x(x_i)=P(x=x_i)=\frac{e^{-\mu}\mu^{x_i}}{x_i!} \qquad x_i=0,1,2,... \qquad (1)$$
$$\mu_x=E(x)=\mu$$
$$\sigma_x^2=\mathrm{var}(x)=\mu$$

The mean value of Poisson distribution in 60 minutes simulation is about 0.029. It equals to 34 (0.029×60(Minute)×20 (Number of nodes)) requests during one simulation. It is not enough for analyze network in high traffics, hence we changed mean value of Poisson distribution with a constant. Furthermore, *Input rate of system* is the product of the number of nodes and the mean value of Poisson distribution [11, 12].

Fig. 6 shows analytical and simulation results of Poisson model. As depicted in Fig. 6-c, the number of iterations should be greater than 1000 times.

5.3. Call Duration Time Model

Life times of calls imitate exponential distribution illustrated in equation 2.

Fig. 7 shows the probability density function of call duration for each request. In the same way exponential distribution has a mean of massage life that it can be decreased or increased for different traffic patterns.

$$f_x(x_i)=\begin{cases}\lambda e^{-\lambda x_i} & 0<x_i<\infty \\ 0 & else\end{cases} \qquad (2)$$
$$E(x)=\frac{1}{\lambda} \qquad \sigma_x^{\ 2}=\mathrm{var}(x)=\lambda$$

5.4. Traffic Load

The required traffic channels for communication is depending on the volume of traffic. Blocking probability is computed using the Erlang B model as equation 3.

$$p_b=\frac{\left(\frac{A^C}{C!}\right)}{\left(\sum_{k=0}^{c}\frac{A^K}{K!}\right)} \qquad (3)$$

where C is the number of traffic channels and $A = N.\mu.\lambda$ that N is the number of users, μ is the average number of call requests per unit time, and λ is the average duration time of a call.

5.5. Performance Metrics

The probability of successful request is:

$$p_s=\frac{NS}{N} \qquad (4)$$

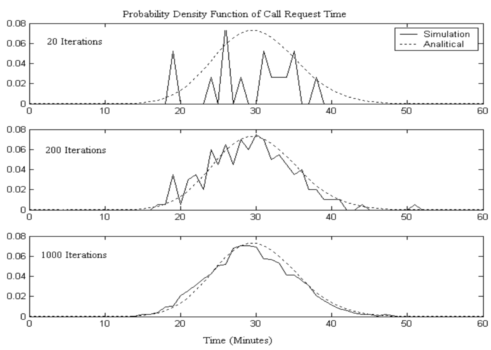

Fig. 6. PDF of Poisson model for different iterations

The blocking probability of requests due to no free channel (or busy) is as follow:

$$P_b = \frac{NB}{N} \quad (5)$$

Forced termination probability due to no free channel in target cell for active call can be achieved by equation 6:

$$P_{FT} = \frac{NFT}{NS} \quad (6)$$

The blocking probability of a request because the received power is under receiver threshold level is:

$$P_F = \frac{NF}{N} \quad (7)$$

Probability of servicing of a call via indirect path, according to Ad-Hoc method, can be found as:

$$P_{AD} = \frac{NAD}{NS} \quad (8)$$

In above mentioned equations, N, NS, NB, NFT, NF and NAD are the number of all requests, successful requests, blocked requests due to no free traffic channel, forced terminated requests, blocked requests because received power is under receiver threshold level, and serviced requests via single, double or triple hops, respectively.

6. Simulation Results

Fig. 8, shows successful and blocking probabilities for different traffic loads in the case of direct path mode. It is clear that high number of requests omitted due to limitation of received

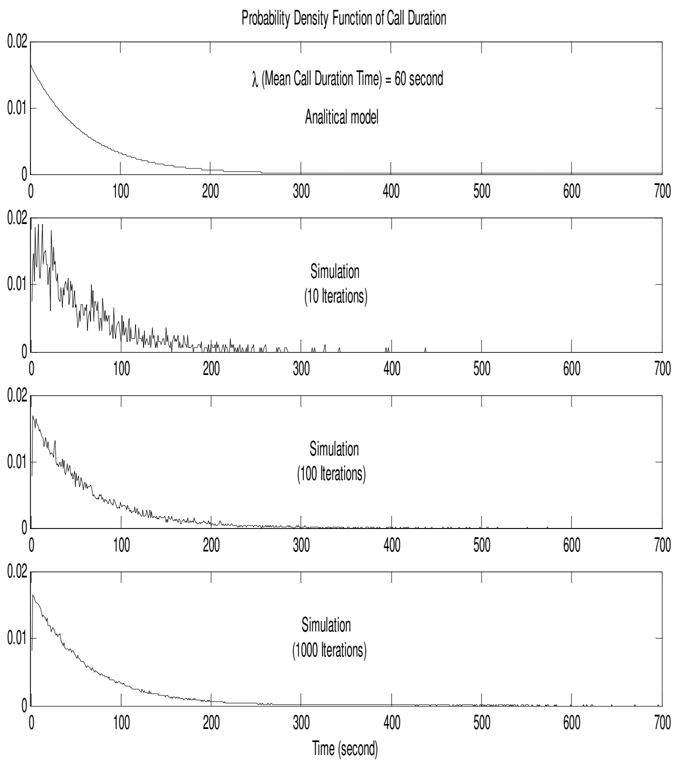

Fig. 7. PDF of negative exponential model for different iterations

power. In the other words, P_F is so high and network doesn't have suitable performance. To analyze the behavior of Ad-Hoc network we had some examination in different Ad-Hoc modes (Single, Double and Triple hops) and derived above mentioned probabilities. These simulations are different traffic loads, some velocities and conversation times.

Fig. 9, shows the variations of above mentioned probabilities for different modes, i.e. direct path and non direct paths (single, double and triple cases). Higher hops introduce better network performance metrics. We increased Ad-Hoc modes up to 3 hops because the maximum distance between two nodes in the simulated structure is 4800 meters and a maximum distance between two nodes which they can communicate together is about 1200 meters. The simulation results show that P_{FT} can be increased and conversation time will be decreased if velocity increases (see the Fig. 10).

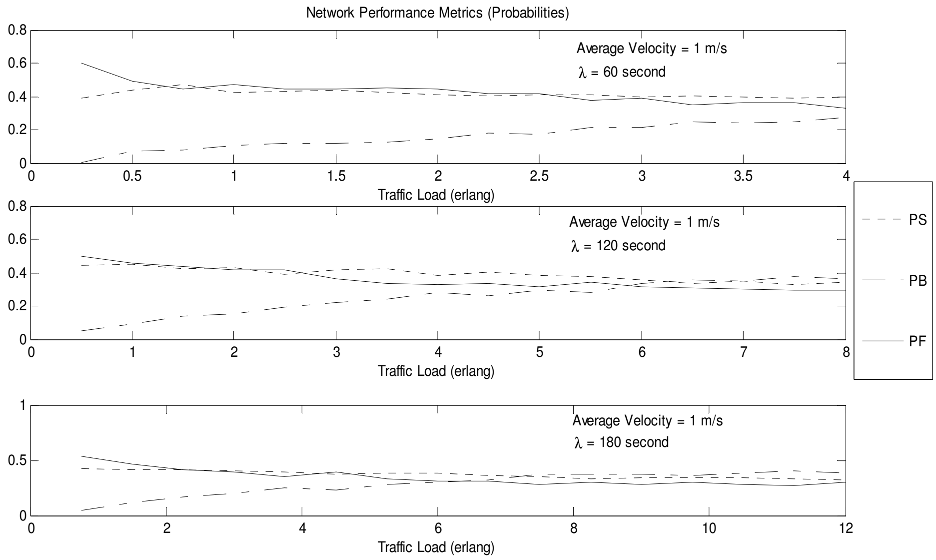

Fig. 8. Successful probability and two types blocking probabilities (PS, PB and PF) versus different traffic loads

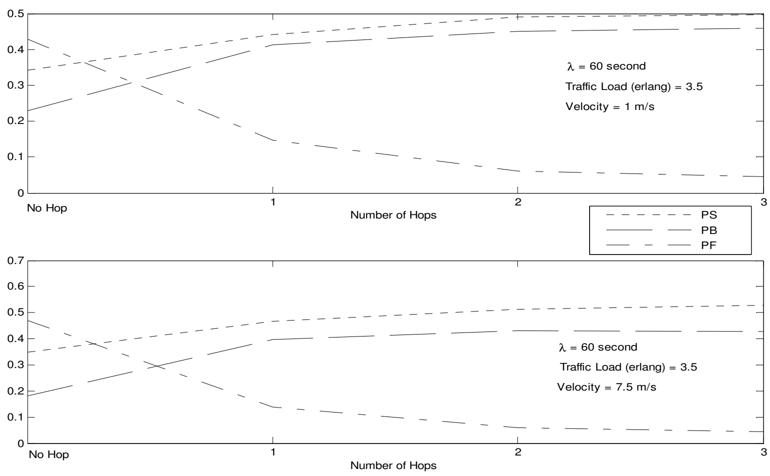

Fig. 9. Successful probability and two types blocking probabilities (PS, PB and PF) versus the number of hops for two different velocities

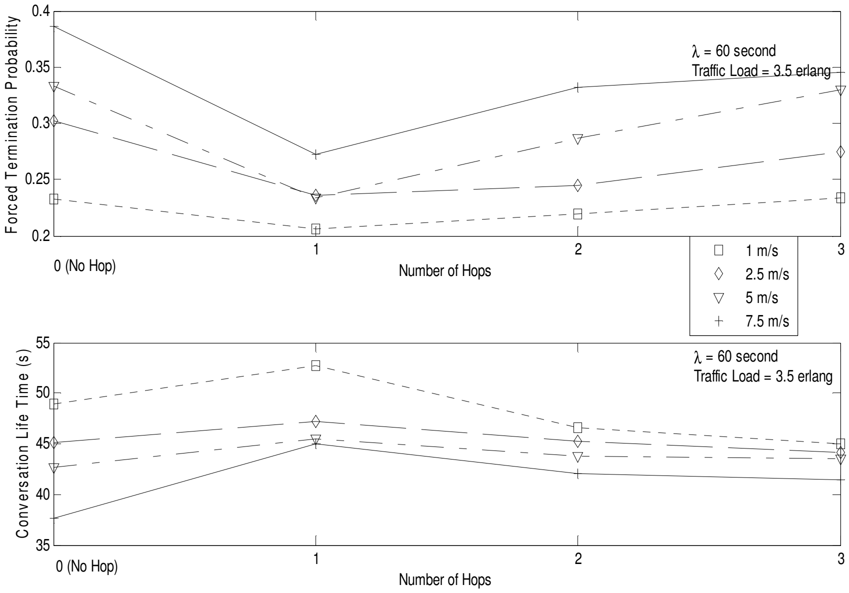

Fig. 10. Forced termination probabilities and conversation times versus the number of hops for four different velocities

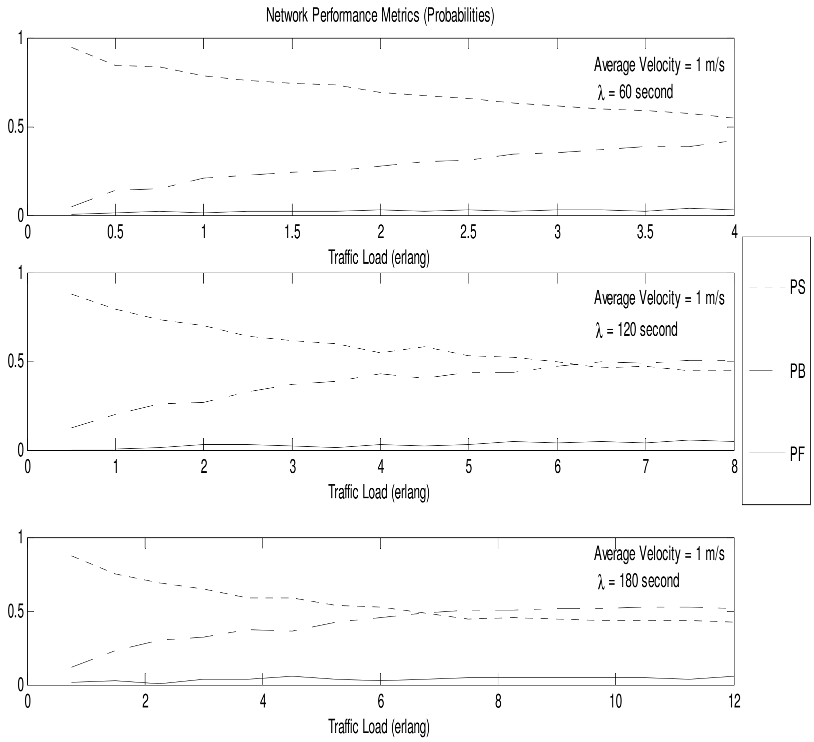

Fig. 11. Performance probabilities of blocking (PS and PF) and successful probabilities versus the number of hops for two different velocities

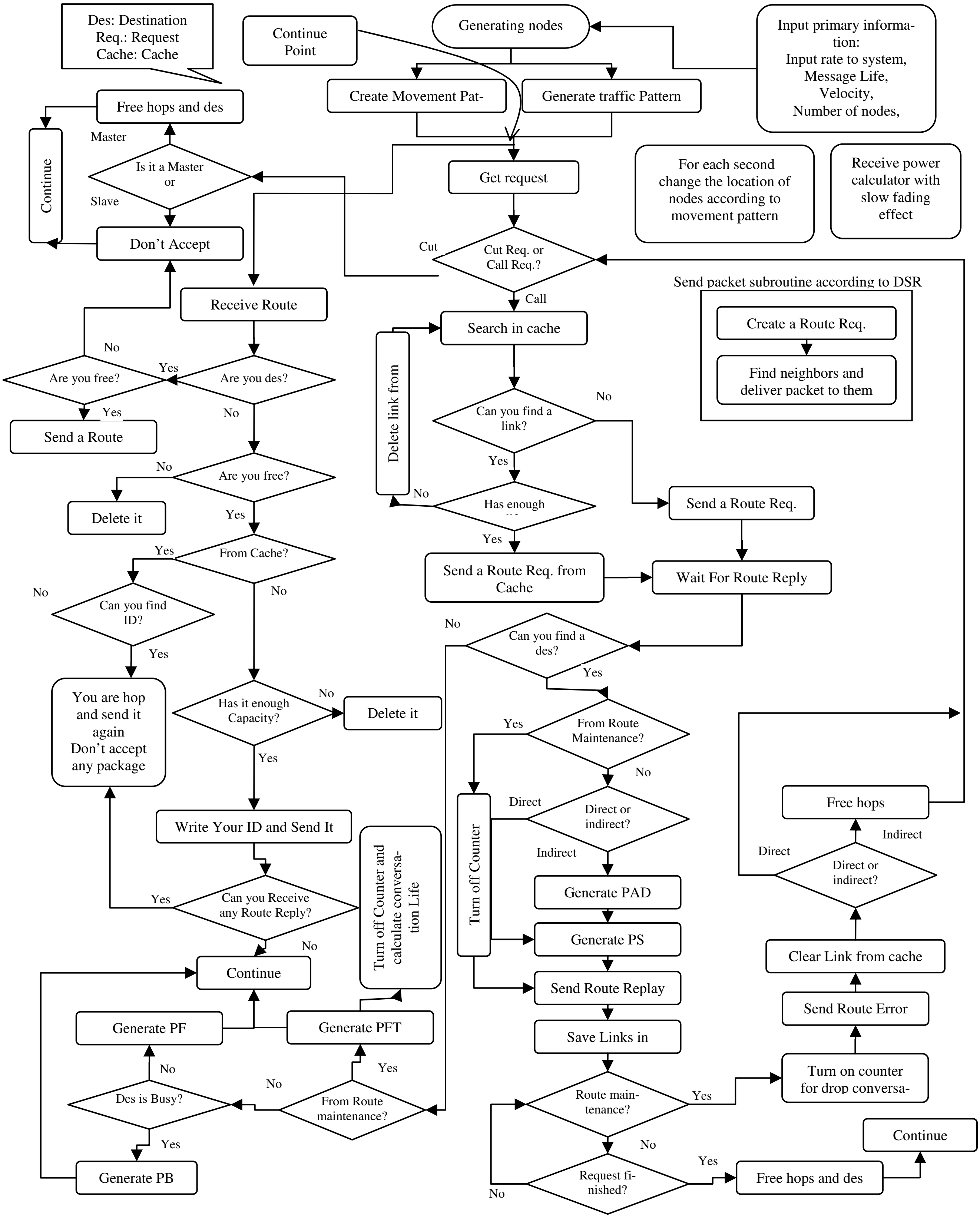

Fig. 12. shows the overall flowchart used to simulating an Ad-Hoc network. It contains some blocks to generate random variables and decision-making and also some boxes to evaluate performance metrics. It should be noted that some boxes including subroutines and hence more details.

7. Conclusions

One of the basic issues in mobile Ad-Hoc networks is routing protocol. In this investigation we had a brief review on DSR protocol. We focused on DSR route discovery as well as route maintenance. Considering a 3400m×3400m structure, direct path communication simulated and performance metrics evaluated. To improve the performance metrics, an Ad-Hoc strategy simulated and performance metrics (Blocking and forced termination probabilities) derived. This Ad-Hoc strategy is an algorithm that according to both traffic and propagation conditions connects two nodes by direct (no hop), single, double and triple hops. Simulation results show more successful rather than direct path connection in multi-hop connection. It has little effects on other probabilities.

For more researches, authors are involved in power control and improvement routing protocol considering better energy saving and lower interference. Improvements will be achieved by considering all parameters and finding a trade-off between performance metrics (probabilities), energy saving and interference. Simulation results will be changed by considering the effect of network topology and type of service (voice, video and data). Also to simulate the effect of these two parameters some new researches will be introduced

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