International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 2 Issue 3 ǁ March. 2014 ǁ PP.10-15

Route Reservation In Adhoc Wireless Networks

Karthiga B.S ,Thresphine J.R
Department of Information Technology
PRIST UNIVERSITY, PUDUCHERRY

Abstract — this paper deals with whether and when Reservation Based (RB) communication can yield better delay performance than NRB Communication in Ad hoc Wireless Networks. In addition to posing this fundamental question (in terms of route discovery, MAC protocol and pipelining etc), the requirements for making RB switching superior to NRB switching are also identified. While the conventional wisdom in current adhoc wireless networking research favours NRB switching, when and under which conditions RB switching might be preferable. Even under these strict and futuristic conditions, while RB switching provide a better delay performances, NRB switching can generally achieve higher network good put and throughput. It is important to understand that if these conditions are not satisfied, then NRB switching will be probable preferable. A novel analytical framework is developed and the network performance under both schemes is quantified. This advantage comes at the expense of lower throughput and goodput compared to NRB schemes.

Keywords— Ad hoc wireless networks, resource reservation, performance analysis, bit error rate, goodput, throughput, delay

I. INTRODUCTION

The two principal switching techniques used in wired networks are circuit switching and packet switching [1]. One of the main differences between them is the way resources are shared. Circuit switching provides exclusive access to the resources by means of reservation. In packet switching, resources are shared on demand, without prior reservation. In this paper, we investigate the performance of two switching paradigms: reservation-based (RB) and non-reservation-based (NRB) switching. The concepts of reservation and non-reservation are analogous to those of circuit switching and packet switching in wired networks, respectively. However, there are some important differences, which can be summarized as follows:

In an NRB (Non Reservation Based) scheme, an intermediate node can simultaneously serve as relay for more than one source. Hence, the resources (in terms of relaying nodes) are shared in an on-demand fashion. This is typical for most of the routing protocols for wireless ad hoc networks proposed in the literature [2].

In an RB scheme, a source first reserves a multihop route to its destination, i.e., it reserves intermediate nodes before the actual transmission begins. The reserved intermediate nodes are required to relay only the message generated by the specific source. This gives the source an exclusive access to the path to the destination. This particular route reservation approach for ad hoc wireless networks was first introduced in [3].

One of the important contributions of this work is to identify under which conditions, the delay performance of the RB scheme can be superior to the NRB scheme.

II. OBJECTIVE OF THE PAPER

To create a new method of establishing and monitoring the routes prior to actual transmission of data. The reserved path could enrich a good way to reach the destination without any loss or corruption or damage of the transmitting data. Although, the main body of this analysis refers to ad hoc wireless networks with fixed nodes, for example, sensor networks and wireless networks, it is also important to extend the scenario with mobile nodes.

III. RESERVATION-BASED (RB) SWITCHING

The principle of operation of an RB scheme is: Prior to data transmission, a source node reserves a multihop route to the destination through a *route discovery phase* [4]. Once an intermediate node agrees to relay traffic for a particular source in the network, it cannot initiate a session or relay messages for any other source until the on-going session is over. The source node releases the route after the session ends.

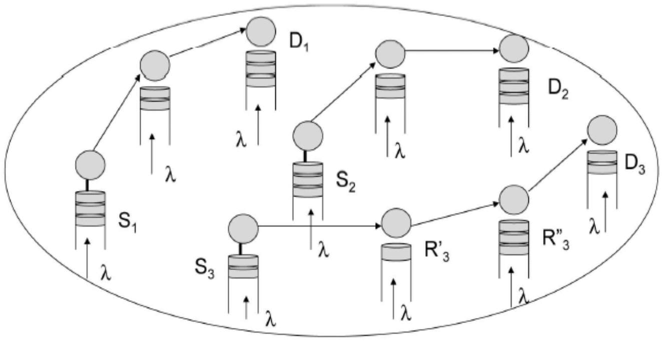

Figure 3.1 Reservation-based ad hoc wireless network models

In other words, the intermediate nodes dedicate their processing time only to the source which reserved the route; however, reservation of a multihop route does not give any node an exclusive access to the shared radio. Fig. 3.1 illustrates an example of reserved routes in a network where an RB scheme is used.

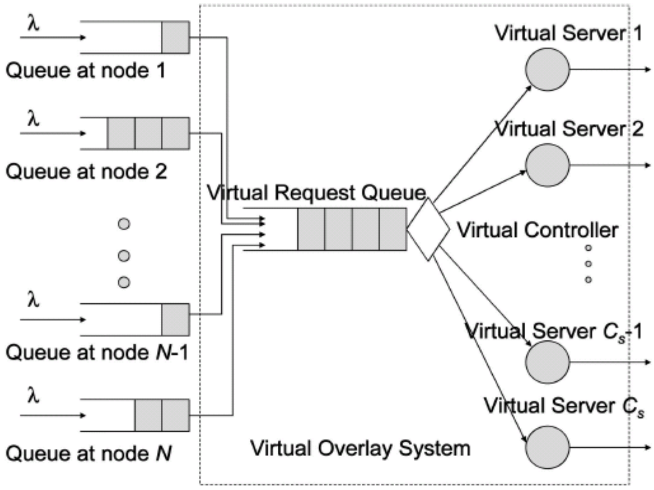

Fig 3.2 Conceptual queuing model for a reservation-based wireless network

IV NON-RESERVATIONBASED (NRB) SWITCHING

In NRB switching, there is no reservation of a route prior to data transmission. As opposed to an RB scheme, in an NRB network communication scenario, multihop routes can *overlap*. In particular, a node can serve as a relay node for more than one route. In other words, when a node receives a message from another node (i.e., it acts as a relay), it places that message in its own queue (intermingled with its own generated messages). The messages in the queue are transmitted sequentially (i.e., the priority given to relay and new locally generated messages is the same). An example of routes in a network with an NRB scheme is shown in Fig. 4.1.

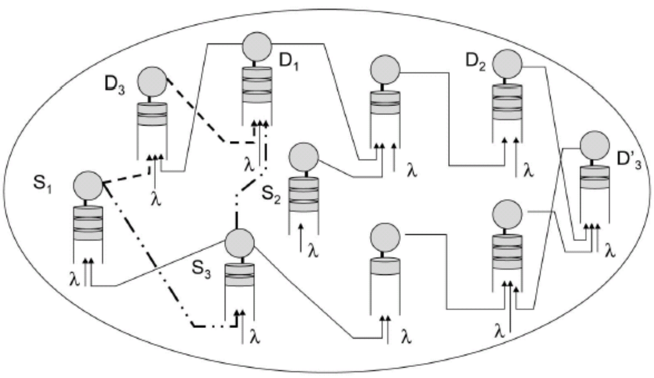

Fig 4.1: Non-reservation-based ad hoc wireless network models

Unlike the case with RB switching, each multihop route is a tandem of queues and the whole network can also be viewed as a tandem of queues. As a result, Burke's theorem can be applied and each individual node can be modeled as an M/M/.1 queue [1]. The conceptual model of an NRB network is shown in Fig. 4.2.

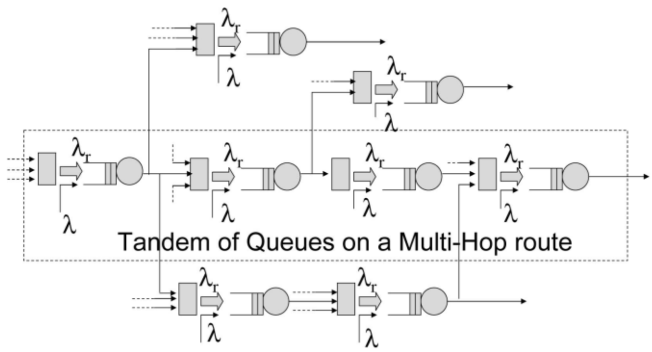

Fig 4.2 Conceptual queuing model for a reservation-based wireless network

V NETWORK MODELS AND ASSUMPTIONS

Network topology: Network Topology considered here is a square grid topology, with N nodes distributed over a surface with finite area A. The node spatial density is defined as the number of nodes per unit area and denoted as _s¼4 N=A (dimension: ½m_2_).

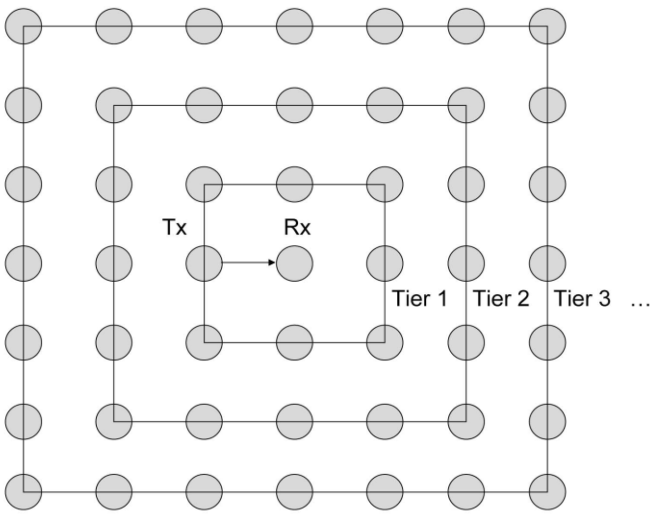

Figure 5.1: Tier structure of a grid network

In square grid topology, each node has four nearest neighbors. An example of such network topology is shown in Fig. 5.1. Due to the structure of the square grid topology, the distance to the nearest neighbor, denoted by r_{link}, is fixed, and a route corresponds to a sequence of hops with equal length.

Typical Routes: In a peer-to-peer ad hoc wireless network, where source/destination pairs are randomly selected, the number of hops in each route is likely to be different. The routes with an average number of hops are typical. Now, the average number of hops in a multihop route in a networking scenario with grid topology is estimated.

Mobility: Although this work refers to ad hoc wireless networks with fixed nodes (e.g., sensor networks [5] and wireless mesh networks [6]), it could be extended to a scenario with mobile nodes.

Assumptions for RB and NRB switching are as follows:

- Each node in the network generates messages according to a Poisson process with average arrival rate _m (dimension: [msg/s]). While a node is acting as a relay, it still generates its own messages, which are buffered for future transmission.
- The message length Lm is exponentially distributed3 with average value Lm (dimension: [b/msg]). Considering a fixed transmission data rate Rb, the message duration is therefore exponentially distributed with a mean value equal to Lm=Rb.
- Since intermediate nodes on a multihop route serve only one source node at a time, simultaneously active multihop routes are disjoint. In addition, given that each multihop route has a certain average length, there exists a maximum average number, denoted by Cs, of simultaneously active routes.
- If the number of nodes wishing to activate a multihop route is larger than Cs, then some nodes have to wait before they can activate the route. The amount of time that a node has to wait before it can activate a route is "access delay."
- The route activation process can be described by a conceptual "virtual request queue" which regulates requests from all sources (see Fig. 2b and Fig. 3).
- The total delay between generation and complete transmission of a message, at each source node, is obtained by adding three terms: 1) the time spent in the node's own queue (denoted by WRB), 2) the time spent in the virtual request queue (denoted by WRB v), and 3) the time spent in the server (denoted by TRB s). In particular, the queue at each node can be modeled as an M=G=1 queue with service time _RB ¼ WRB v þ TRB s.
- The combination of the virtual request queue and the Cs virtual servers will be denoted as "virtual overlay system." In particular, there are N flows of information at its input, coming from the N nodes.

VI ANALYSIS OF DELAY OF TWO SWITCHING TECHNIQUES

In an RB Switching scheme, With the assumptions specified in Section 4.1, each node is modeled as an M=G=1 queue. The average delay that each message experiences is equal to the sum of the mean waiting time in the source queue, denoted as E½WRB o _, and the mean service time E½_RB_, where, as previously defined, _RB ¼ WRB v þ TRB s . The mean waiting time in an M=G=1 queue can be computed using the Pollaczeck-Khinchin formula [1]:

$$E[W_o^{RB}] = \frac{\lambda_m E[\tau_{RB}^2]}{2(1-\lambda_m E[\tau_{RB}])} \tag{1}$$

It is clear from (1) that that one needs to compute the first and second moments of the service time τ_{RB}, which can be derived from the statistics of the total time spent in the M/M/Cs/1/N virtual overlay system. The probability density function (pdf) of the time spent in the M/M/Cs/1/N system is [32]

$$f_{\tau_{RB}}(x) \triangleq \mu\epsilon^{-\mu x}\sum_{n=0}^{C_s-1} a_n + \sum_{n=C_s}^{N-1} a_n \left[\begin{array}{c} \mu\epsilon^{-\mu x}\left(\frac{C_s}{C_s-1}\right)^{n-C_s+1} \\ -\mu\left(\frac{C_s}{C_s-1}\right)^{n-C_s+1}\sum_{r=0}^{n-C_s} e^{-\mu x}\frac{[\mu(C_s-1)x]^r}{r!} \end{array}\right] \tag{2}$$

Where a_n is the probability that a new arrival finds n "customers" in the virtual overlay system (i.e., n nodes are transmitting or waiting to start transmitting an already generated message), and is the average service rate.

The probability distribution $\{a_n\}$ of the number of customers that a new arrival sees in an M/M/Cs/1/N system involves the computation of large factorials (e.g., N!), which leads to numerical problems. To analyze a large-scale ad hoc network, we exploit the fact that when the number of sources is large, the steady-state probability distribution of an M/M/Cs/1/N system follows that of an M/M/Cs system [32]. The first and second moments of the time that each message spends in the system are given by

$$E[\tau_{RB}] = \frac{1}{\mu} + \frac{\Gamma(C_s, \frac{\lambda_m}{\mu})}{\mu C_s - \lambda_m} \tag{3}$$

$$E[\tau_{RB}^2] = \frac{2}{\mu^2} + \frac{2\Gamma(C_s, \frac{\lambda_m}{\mu})}{[\mu C_s - \lambda_m]^2} \tag{4}$$

where

$$\Gamma(C_s, \frac{\lambda_m}{\mu}) = \left[\sum_{n=0}^{C_s-1} \frac{\left(\frac{\lambda_m}{\mu}\right)^2}{n!} + \frac{\left(\frac{\lambda_m}{\mu}\right)}{C_s!\left(1-\frac{\lambda_m}{\mu C_s}\right)} X \frac{\left(\frac{\lambda_m}{\mu}\right)^{C_s}}{C_s!\left(1-\frac{\lambda_m}{\mu C_s}\right)}\right] \tag{5}$$

Since the route is reserved, it is possible to transmit a message from source to destination using a pipelining method. Assuming that the whole message of length L_m bits is divided into packets of fixed length l_p bits, the total number of packets per message is L_m/l_p. Suppose there are n_h links on a route from source to destination. The total time to transmit a message with a pipelining method can be computed as

$$\tau_S^{RB} = \frac{L_m}{R_b} + (n_h - 1)\frac{l_p}{R_b} \tag{6}$$

Consequently, the total transmission time T_s^{RB}, as given in (5), is not exponentially distributed. This violates the exponential service time assumption. However, if $L_m \gg n_h l_p$, then the second term on the right hand side of (5) is negligible, and the exponential service time assumption still holds.

In the case of retransmission, the message transmission time can be generalized as

$$T_S^{RB} = \frac{L_m}{R_b}(1+K) + (n_h - 1)\frac{l_p}{R_b}(1+K) \tag{7}$$

where K is the number of retransmissions per link. Since K is a discrete random variable, the transmission time becomes a function of two random variables (L_m and K). The pdf of the total delay in this case can be written as

$$fT_s^{RB}(t) = \sum_{j=0}^{\infty}\left[\frac{\mu e^{\frac{\mu t}{1+j}}}{1+j}\right][(PER_{link})^j(1-PER_{link})]u(t) \tag{8}$$

where u(t) is the unit step function, defined as

$$u(t) \triangleq \begin{cases} 1 & t \geq 0 \\ 0 & t < 0 \end{cases} \tag{9}$$

In particular, (8) can be derived directly from the total probability theorem; the expression in the first square bracket is the conditional pdf of the transmission time given that the number of retransmission is j, and the expression in the second square bracket is the probability mass function of the random variable K.

The pdf given in (8) is not exponential, and it may not have a closed-form expression. Fortunately, given that the number of retransmissions is j, the conditional pdf of the transmission time has the following exponential structure:

$$fT_s^{RB}\left(\frac{t}{j}\right) = \frac{\mu}{1+j}e^{\frac{\mu t}{1+j}}u(t) \tag{10}$$

Consequently, even in the case of retransmissions, one can still analyze the delay performance of the network communication system using the same queuing model, but with a modified service time. From (10), it can easily be observed that the new mean service time is $\frac{1+j}{\mu}$. To take advantage of this, the number of retransmissions j must be specified. To be conservative, the number of per-link packet retransmissions which will be used in the following is the *maximum* number of retransmissions is denoted by k_{max} . In this case, the service time is exponential with mean service time $\frac{L_m(K_{max}+1)}{R_b}$

In NRB, since each source does not have a dedicated route, a message transmitted in a route will experience, in addition to the transmission delay, a queuing delay at each node it traverses. According to the applicability of Burke's theorem to an NRB switching network [1]), the average delay that a packet experiences at each node it traverses corresponds to that of an M/M/1 queue and is given by

$$E[T^{NRB}] = \frac{1}{\frac{R_b}{L_m} - \lambda_{\text{total}}} \tag{11}$$

The total average delay for a message from the source node to the destination node of a multihop route is obtained as the sum of the average delays experienced at each intermediate node. In other words, $E[T_{total}^{NRB}] = n_h E[T^{NRB}]$.

Given that the average number of retransmissions is K_{max} , the service time for transmitting a packet is still exponentially distributed. If a message of size Lm bit is divided into packets of fixed length lp b/pck, this time it takes to transmit a single packet is (1 + K_{max}) / R_b. Since there are L_m/p_b packets in a message, the time the last packet will reach the next hop is (1 + kmax) L_m/R_b. Hence, in the case with retransmission, the expected per-link message transmission time in (2) is given by

$$E[T^{NRB}] = \frac{1}{\frac{R_b}{L_m} - \lambda_{\text{total}}} \tag{12}$$

VI CONCLUSION

This work answers an interesting question: if and when reservation-based switching makes sense in contemporary wireless ad hoc networks. If the right requirements (in terms of route discovery, MAC protocol used, pipelining, etc.) are met, then RB switching schemes can provide better delay performance than NRB switching schemes. In return, the throughput and goodput performance of NRB schemes, even under these somewhat stringent requirements, seem to be superior to RB schemes. This paper also provides the analytical framework and model (queuing models) developed for analyzing the network performance (in terms of delay) under the RB and NRB switching schemes. While RB schemes can provide better delay performance, NRB schemes support higher traffic loads than RB schemes. In addition, NRB schemes can support a higher number of routes because there is no constraint for the routes to be disjoint. Finally, RB schemes are more robust to node mobility than NRB schemes.

REFERENCES

[1] D. Bertsekas and R. Gallager, *Data Networks.* Prentice Hall, 1992.
[2] E.M. Royer and C.-K. Toh, "A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks," *IEEE Personal Comm. Magazine,* vol. 6, no. 2, pp. 46-55, Apr. 1999.
[3] G. Ferrari and O.K. Tonguz, "Performance of Ad Hoc Wireless Networks with Aloha and PR-CSMA MAC Protocols," *Proc. IEEE GLOBECOM,* pp. 2824-2829, Dec. 2003.
[4] C.E. Perkins, *Ad Hoc Networking.* Addison-Wesley,2001.
[5] I. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A Survey on Sensor Networks," *IEEE Comm. Magazine,* vol. 40, no. 8, pp.102-114, Aug.2002.
[6] B. Schrick and M.J. Riezenman, "Wireless Broadband in a Box," *IEEE Spectrum,* vol. 39, no. 6, pp. 38-43, June 2002.