Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 15 (4): 703-708, 2015
ISSN 1812-5654

ansinet
Asian Network for Scientific Information

RESEARCH ARTICLE OPEN ACCESS

DOI: 10.3923/jas.2015.703.708

End-to-End Route Reliability in Pervasive Multi-Channel Multi-Radio (PMCMR) Scheme for MANETS

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ARTICLE INFO
Article History:
Received: January 18, 2015
Accepted: January 26, 2015

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ABSTRACT

Multi-channel multi radio wireless communications technologies have changed the trend of traditional routing based Quality of Service (QoS) in wireless-mesh networks. This avalanche of growth in multimedia communication is trigged by Multi-Channel Multi-Radio Wireless Mesh Networks (MCMR-WMNs). It is forecasted that in the near future, societal networks will have latest state of the art radio devices with Multi Channel and Multi Radio (MCMR) communication power with enhanced reliability, throughput and self-healing features. Despite of marked improvements in data link layer and physical layer in the IEEE 802.11 standards, optimized throughput, performance and network availability of MCMR wireless mesh networks still depend upon the efficient routing metric or protocol. We carried out a set of experiment and observed that cross layer routing in mesh networks is highly influenced by traffic load, interference between channel and interference between nodes. Proposed scheme used 'conjugate distribution method' which was designed to evaluate end-to-end route and communication reliability using posterior distribution function. Routing metric is evaluated based on load aware, intra and inter-interface aware, packet average delivery ration, latency and overhead with considered criteria of average path length. Competitive study revealed that proposed technique is efficient and applicable especial in environment where end-to-end reliability is required.

Key words: Protocol design, wireless mesh network, multi-channel, multi-radio, routing

INTRODUCTION

Wireless networks have become widespread in autonomic communication because of improvements in mobile computing. *Ad-hoc* network represents a distinct category of wireless mesh networks which is a group of mobile wireless nodes fashioned without any prior fixed communication device arrangement or any regular services. In *ad-hoc* network the routing and the transceiver management are recognized over diverse nodes in disseminated way and numerous nodes are associated to each other for control and payload packet delivery. In MANETS each portable (node, sensor, sink) device acts as host and router. Majority of *ad-hoc* networks do not have any requirements for limiting or control the packet stream that pass through a node.

The diverse features of MANETS as compared to their traditional wired networks, highlight numerous concerns such as motion of nodes, imperfect bandwidth, error-prone broadcast channels and energy limitations.

Moreover, multi-channel multi radio wireless communications technologies have transformed the tendency of legacy Voice over IP (VoIP) and Video over IP (Video IP) communication in general networks. This immense evolution in multimedia communication is trigged by Multi-Channel Multi-Radio Wireless Mesh Networks (MCMR-WMNs). It is predicted in future, general networks will have state-of-the-art radio devices with MCMR reliability enabled packet delivery, throughput and autonomic features. Regardless of obvious enhancements in data link layer and physical layer in the IEEE 802.11 standards, improved throughput and network accessibility of MCMR wireless mesh networks still needs an efficient routing protocol.

At present, there are many routing protocols with numerous variances and likenesses between them, that represents a number of recompenses and shortcomings when applied to MANETS. Each protocol has distinctive features with makes it appropriate for a certain application. To develop a full performed routing protocol, it is mandatory to comprehend the two processes of routing protocols: Non-adaptive algorithms and adaptive algorithms (Ab Rahman *et al.*, 2011; Kong *et al.*, 2009). Non-adaptive protocol calculates the route upon network initialization and not centered on cluster topology however adaptive protocol is cognizant about topology and related information.

Adya *et al.* (2004) recommended a link-layer solution for transferring data over several radio interfaces but this approach is formulated for situation where the number of radio interfaces and channels are identical. In a study by Ali *et al.* (2009) channels were associated diverse static integrated algorithms but for assessment of optimum number of radio edges was used only one constraint-total intrusions (quantity of associations in conflict graph).

The amalgam is a procedure where a definite set of nodes intermittently apprises the node route information of desired destinations and tries to establish a suitable use of the two earlier methods. Examples of hybrid protocols are: Hybrid wireless mesh protocol (Bhar, 2007), Zone Routing Protocol (ZRP) (Haas and Pearlman, 2001), AODV (Clausen and Jacquet, 2003) and OLSR (Saeed *et al.*, 2012; He *et al.*, 2003).

NACS (Tariq *et al.*, 2005) is a non-overlapping AP's caching scheme which broadcasts the mobile node setting to those access points which do not overlay with the current connection point. To explore the topology of non-overlapping peers in the wireless network, non-overlapping graph is produced at each transceiver.

In a study by He *et al.* (2003), SPEED protocol illustrated real-time end-to-end reliability matrix. Every node keeps information of connected peer and afterward uses the location-based routing to discover the ideal paths. It also promises the definite speed of the packet distribution, so that the application predicts the end-to-end adjournment and the speed of packets transfer by calculating (hop count by TTL value) the distance between the source and sink. SPEED also delivers flash-crowd evasion in case of network congestion.

Numerous cross layer routing metrics are presented in the literature that purposes to expand the general performance of MANETS. In this study, we adopted the essential network to be a MANET that characteristically experiences continuous topology deviations which interrupt the stream of information over the current paths. Proposed research intended to evaluate the parameters of incorporation and low-power operation in the design of basic wireless mesh platforms for the application of proposed mechanism.

METHODOLOGY

Proposed scheme: MANETs use three types of routing protocols: Proactive, reactive and hybrid. In proactive protocol, all nodes behave as a router and maintain zonal or complete route information to choose best possible route to ensure QoS for multimedia (VoIP and Video) communication. Our scheme considered selection of best possible path for each incoming connection and optimized use of network nodes to balance the network usage (i.e., to avoid flash crowds and battery outage at connection sensitive wireless nodes). Reactive protocol is on-demand destination route discovery and selection protocol. In hybrid protocol, selected nodes are responsible for route discovery and route selection for whole network.

To deliver packet at destination link, routing tables used following information at each routing table entry (Table 1, 2):

- Destination Type (used when forwarding data IP packet)
- Network (a range (class A, B, or C) of IP addresses which leads to end point)
- Area Boarder Router (to generate 'route initiate summary link advertisements')
- Destination Identifier (to identify connected IP addresses)
- Type of Service (for each type of IP ToS there can be a different route)
- Cost (complete alleyway cost based on qualitative or quantitative data forwarding)
- Link State Origin (router links or network links, used to calculate routing table)
- Next Hop (IP address of next router or destination)
- Advertising Router (router ID of available packet forwarding node)

Upon receipt of a data packet, router check routing table to select best possible dependent (i.e., multimedia (VoIP, Video) data) route. In case, destination IP is not in routing table list, an Internet Control Message Protocol (ICMP) packet is sent to source IP indicating unavailability of destination link in given zone. Each direction-finding entry will require the same range of IP addresses but a different ToS. PMCMR scheme, nominated the routing table record whose ToS value matches the ToS found in packet header.

Table 1: Router link advertisement

Link State (LS) age	Options | 1
Link state identification	
Advertising router ID	
Link state order numeral	
Link state checksum	Length (advertisements in bytes)
Virtual link endpoint | external | border	Number of Links
Link identification	
Link data (32 bits information for link)	
*Type | Type of Service (ToS) | To Smetric	
Link identification	
Link data	

*Type 1: Point-to-point link to connected routers, 2: Virtual link, type description (Hello, LS request, LS update, LS ACK)

Table 2: LS invitation packet

Version number | 1 | packet length
Router identification
Zone identification
Checksum | authentication | authentication type (hello interval, link dead interval, neighbor)
LS type (1 or 2)
*LS identification
Link advertiser

*Link identification 1: Neighbor router route identification, 2: Router's IP address, 3: Subnet number

End-to-end communication reliability: In wireless mesh networks, each eligible node works as router and can hold or distribute Routing Table (RT) to its affiliated nodes. PMCMR scheme used 'conjugate distribution method' which was designed to evaluate end-to-end route and communication reliability using posterior distribution function. With this in mind, we assumed collective communication failure detection as:

$$DY(d;\theta) \text{ if } \theta \in \Theta$$

where, $y(d, \theta)$ is the probability concentration function and θ signifies the dependability metric to be established. Prior distribution function of θ is $Q(\theta)$ and analogous node compactness function is $q(\theta)$. The common probability compactness function of (D, θ) is then:

$$y(d, \theta) = y(d \mid \theta).q(\theta) \quad (1)$$

The negligible dissemination of the common detected failure number D is then:

$$e(d) = \int_{\Theta} y(d \mid \theta).q(\theta) x\theta \quad (2)$$

As per Bayesian theory (Quer *et al*., 2012), assumed D, the qualified probability node concentration function:

$$q(\theta \mid d) = \frac{y(d \mid \theta)}{e(d)} = \frac{y(d \mid \theta).q(\theta)}{\int y(d \mid \theta).q(\theta) j\theta} \quad (3)$$

where, $q(\theta|d)$ is the subsequent probability node compactness function of θ.

Given the end-to-end 'routing trustworthiness demonstration index (θ_0, b, s)', where θ is maximum acceptable failure rate (e.g., node failure, route failure, etc.,), b illustrates node's confidence level and s is the acceptance value of node/router/packet-delivery failure during communication.

In case a node (new or mobile) joins topology cluster using 'Non Overlapping Neighbor Caching Scheme' (Tariq *et al*., 2005) the required time to establish/obtain routing table is the minutest t sufficient. Nodes periodically announce their presence in cluster by broadcasting 'Hello Packet' to its neighboring nodes:

$$(\theta \le \theta_0) = \int_0^{\theta_0} q(\theta \mid s, t) j\theta \ge b \quad (4)$$

where, $q(\theta)$ calculated by statistical techniques using previously obtained failure data which also leads to obtain qualified probability node concentration.

To obtain end-to-end wireless communication reliability, node density plays an important role over the selected routes. PMCMR supposed that $y(d)$ is the cluster node density function of a random variable D. Then if,

$$y(d) = b\, e(d)$$

where, b is persistent autonomous factor of d and $e(d)$ is a fragment reliant of d, we say $e(d)$ is the cluster of $y(d)$:

$$y(d) \propto e(d)$$

Thus choosing the preceding dissemination function means selecting a diminishing function of reliability metric θ which is failure rate of cluster head/node in relevance of cluster density. In proposed scheme, preceding dissemination function is used to reveal the route reliability. For this purpose, we embrace the collective detected packet delivery failure rate is:

$$DY(d;\theta)$$

where $\theta \in \Theta$ The marginal possibility density function of the failure threshold *'a'* is then:

$$\begin{aligned} e(a) &= \int_0^1 e(s, m, a) ja = (p+1)B_m^s \int_0^1 a^s (1-a)^{p+m-s} \\ &= (p+1)B_m^s Z(s+1, p+1+m-s) \end{aligned} \quad (5)$$

If s failures are identified after m communications (between node-to-node, node-to-gateway, node-to-sink) then subsequent probability density function of failure possibility m is given by:

$$b(a \mid s, m, a) = \frac{e(s, m, a)}{e(s, m)} = \frac{a^s (1-a)^{p+m-s}}{Z(s+1, p+1+m-s)} \quad (6)$$

The mathematical anticipation of the failure number D of the route/packet-wormhole during time interval [0,1] as per s where l is provisional probability of failure rate and it tracks poison distribution with factor λt.

$$F(D) = \sum_{s=0}^{+\infty} s.e(d=s) = \sum_{s=0}^{+\infty} \frac{pst^s}{(p+t)^s} = \frac{t}{p} \quad (7)$$

Equation 7, describes the value of hyper-parameter p determined by time t and F(D) which was altered into sequence of sample of failure based time intervals $(t_1, t_2, t_3, \ldots, t_n)$.

We set the tolerable number of failures to 0, the optimized time for fully functional multi-channel route is:

$$A(\lambda \le \lambda_0) = \int_0^{\lambda_0} y(\lambda \mid 0, t, p) j\lambda = \int_0^{\lambda_0} (\hat{p} + t)^{s+1} \lambda^s i^{-\lambda(\hat{p}+t)} j\lambda \ge b \quad (8)$$

Channel selection and negotiation criteria: PMCMR scheme adopted 'dynamic channel allocation' criteria, where interfaces are permissible to change to different channels with less frequent channel switching strategies (Ramachandran *et al.*, 2006; Pediaditaki *et al.*, 2009; Dhananjay *et al.*, 2009). A principal server screens for environmental variations, reallocates the channel assignment for entire network and notifies the nodes to switch to appropriate channel on periodic intervals. For increased network throughput scheme used 'directional antenna network' with various orthogonal channels such as (Dutta *et al.*, 2007).

Proposed scheme describes channel conciliation criteria (i.e., awaiting node, referring node and delivery node) in Algorithm 1.

Algorithm 1: Channel conciliation

Awaiting node
1. Broadcast A-Node-Request message to notify that 'A' is an awaiting node
2. If getting Channel-Switch-Command then
3. Switch channel as per message
4. End i

Referring node
1. If queue length of receiving length is smaller than queue threshold then
2. Broadcast A-Node-Request message to all neighboring nodes to inform that it can send packets and packet congestion is below overload.
3. End if

Delivery node
1. If queue length of receiving length is smaller than queue threshold then
2. If getting A-Node-Request then
3. Send Channel-Switch packet to its channel and awaiting node
4. End if
5. If receiving A-Node-Request then
6. command channel-switch to referring node
7. End if
8. End if

RESULTS AND DISCUSSION

We simulate PMCMR in network simulator (ns-3, 2015). We implement the simulation on an arbitrary topology of 58 nodes in a 1000×1000 m zone (Fig. 1). Each transceiver has minimum three neighbors and at most ten adjacent nodes within signal communication range (signal strength is calculated using Received Signal Strength Indication (RSSI technique). The average degree of the nodes is 4.3. We established 30 Unified Datagram Protocol (UDP) flows with each packet size of 500 bytes. All data points are at typical rate of fifteen simulation runs where each altered run relates to a different indiscriminately created mobility setting with matching traffic models. Network simulator parameters are shown in Table 3.

Network assumptions: This protocol depends on a following network assumptions.

- Open Systems Interconnection (OSI) physical layer is able of functioning using multiple rates
- In OSI layer 2 (data link), Media Access Control (MAC) is able of choosing the frequency used by the physical layer
- The MAC layer is able of furnishing data to the OSI network layer that specifies the chosen rate which will help it to adopt better routing decisions

Figure 2 shows the average throughput, attained by PMCMR, HYMP (Bhar, 2007) and ZRP (Haas and Pearlman, 2001) influenced by the number of nodes in the environment area. It represents that the average throughput is diminished with reduced network density (throughput has directly proportional relationship with densely populated connected nodes i.e., more connected neighbors will furnish high throughput). PMCMR constantly accomplishes the highest throughput in the assessed cases. It designated higher throughput routes and tends to elude lengthy untrustworthy links which diminishes the over-all medium time spent transferring packets from a source to a destination. It is worth noticing that NS-3 simulator used preconfigured transferor sense threshold (-80 dBm) and preconfigured receive threshold (-65 dBm).

Figure 3 illustrates the packet flow based energy consumption is calculated by the:

$$\frac{\text{Total energy usage}}{\text{Total sum of packet received}}$$

Table 3: Network simulator parameters

Factors	Value
Area	1000×1000
Transmitting nodes	58
Rate of recurrence (GHz)	2.4
Indication power (dBm)	20
Receiver threshold (dBm)	-65
Carrier sense threshold (dBm)	-99
System loss (dBm)	0
Sender sense threshold (dBm)	-80
Initial energy (J)	55
Pause time (sec)	3
Network interface type	Wireless phy

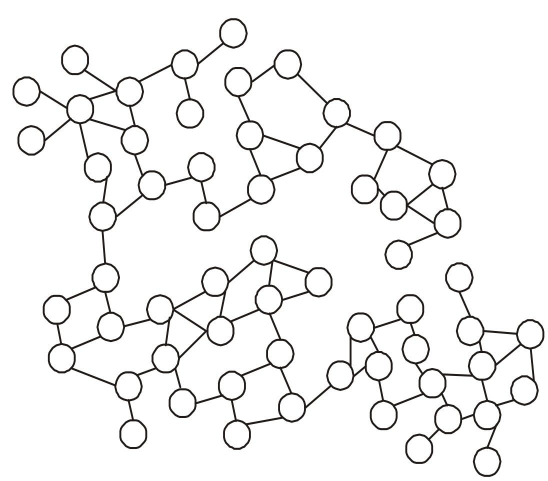

Fig. 1: Topology of the PMCMR with 58 nodes

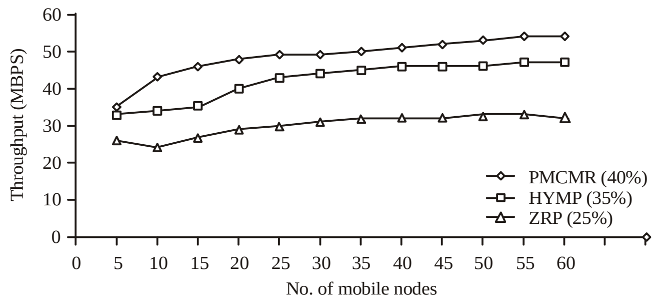

Fig. 2: Average throughput with different node densities

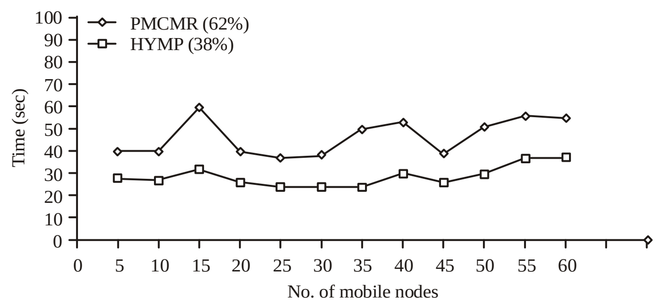

Fig. 3: Battery lifetime for packet (ICMP, Payload) traffic for 58 nodes

The energy efficiency is represented in 'Joule' and the larger the numeral of bytes/joule, shows improved efficiency. Energy efficiency is better in proposed protocol because every node is responsive of its energy limitations for packet communication. Moreover, PMCMR selects the route with more nodes with greater energy level and establish an extended life of network system, consequently achieves a more stability of energy consumption.

CONCLUSION

As MANET operations entirely depends on mutual aid and systematic behavior of communicating nodes, it is hard to establish optimum QoS. We evaluated the effectiveness of the proposed algorithms with the prominent multi-channel routing algorithms. Simulation results showed that PMCMR is functional, encounter fewer channel conflicts with nominal radio network interference. Although scheme adopted nearest node and shortest routing path method but in some cases high packet latency was observed due to flash crowds near sink node in multicast based topology. Depending on network density our simulation demonstrated 40% average throughput by choosing minutest hop counts from source to destination node. Energy-aware route selection provides the longer life to overall network.

ACKNOWLEDGMENT

This project was supported by the Deanship of Scientific Research at Salman Bin Abdul Aziz University under the research project No. 2014/01/1807.

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