CROSS LAYER DESIGN FOR ROUTING IN MULTI-HOP WIRELESS NETWORKS

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Abstract:

Multi-hop wireless networks are facing some research issues regarding routing protocols. Multi-hop decentralized architecture, media access delay, lower link life and bandwidth estimation are the key challenges which need to be address. The selection of optimal path with available bandwidth for routing cannot be achieved with the traditional approaches. Cross layer design is the only solution to cope with these kinds of challenges in multi-hop wireless networks. In this system, we will discuss the importance of cross layer routing protocols for multi-hop wireless networks by critical comparison.

Keywords: Multi-hop, Cross-layer design, Available bandwidth.

1. Introduction

Wireless networks for mobile and broadband applications have emerging and growing trends. Such kind of fast changes in communication technologies and emerging trends stress to optimize the performance of the multi-hop wireless networks. However, the OSI stack which is responsible for end to end communication was primarily designed for wired networks, which cannot perform well in multi-hop wireless networks, as the higher layers and their residing protocols remained unaware of the underlying protocols. Multi-hop wireless networks impose new challenges such as, the varying nature of the signal strength, higher bit-error rates, dynamic variations in channel quality, fading effects, interference problems, mobility, shared and contention based MAC, Multi-hop transmission and path selection at network layer needs some degree of interaction amongst different layers so that to optimized the overall network performance. In order to solve such problems, cross layer information exchange is proposed in [7, 8]. The basic purpose of cross-layer design is to use multilayer parameters from OSI stack to increase the efficiency and performance of multi-hop wireless networks. Cross layer design approach can be used to improve the overall performance of multi-hop wireless networks such as wireless sensor networks (WSN), mobile ad hoc networks (MANET), and wireless mesh networks (WMN).

Definition:
The available bandwidth can be defined as the maximum throughput that can be transmitted between these two peers without disrupting any ongoing flow in the network.

2. Estimating a link's available bandwidth

Let us now consider a radio link composed of two neighbor nodes *s* and *r*. We use the following notations:

- δ is a time unit when considering discrete time.
- $\tau_{m=\Delta/\delta}$ is the number of time units in a period or measurement.
- τ_s (resp. τ_r) is the number of time units during which the medium is available for node *s* (resp. *r*).
- B_s (resp. B_r) is the available bandwidth at node *s* (resp. *r*).

- $B_{(s,r)}$ is available bandwidth on the link (s,r).
- $B_{(s,r)}$ is the estimated available bandwidth on the link (s,r) when not using the RTS/CTS handshake.

If the available bandwidth on *s's* side is null, s will either never gain access to the medium or put the medium in saturated mode. Similarly, if the medium is always occupied on the receiver side, *s's* emissions will systematically collide and the communication will never succeed. Trivially, we can state that $B_{(s,r)} \leq \min(B_s, B_r)$. Adding a flow with a throughput higher than $\min(B_s, B_r)$ will necessarily saturate the medium around s and/or r. In a wireless environment, compared to wired networks, the medium state is not identical at two different locations due to the high attenuation of radio signals in the air and the equality does not necessarily hold. For the communication to take place, the medium has to be simultaneously available on both sender and receiver's sides. Even with a low global medium idle periods of the receiver and the sender, as shown on Figure 1. On Figure 1, the periods of medium availability of both peers never overlap and the available bandwidth on the link in null.

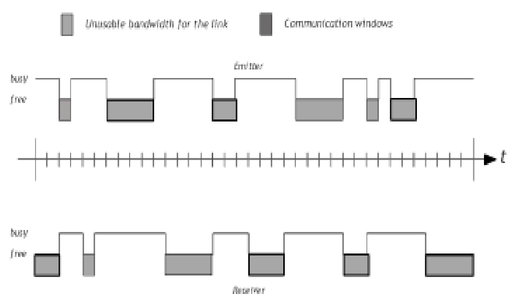

Figure 1. Worst case: medium availabilities of sender and receiver never overlap.

Since in ad hoc networks, the nodes are unlikely to be synchronized, we propose a prediction mechanism to compute the available bandwidth computed at each node.

3. Estimated bandwidth without RTS/CTS

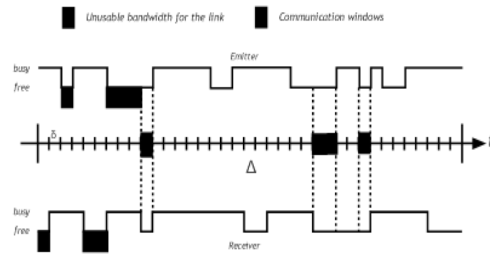

Figure 2. Sender and Receiver synchronization without RTS/CTS

Due to space limitations, we don't give the results with RTS/CTS but the same kind of computations can be deduced. If no RTS/CTS are used, communication can only take place when the medium is physically free at both sender and receiver's sides. Still considering a random uniform distribution of the medium occupancy, the available expected bandwidth $E(b_{(s,r)})$ can be evaluated using the following formula.

$$P(b_{(s,r)} = i) = \frac{\binom{T_s}{i} \cdot \binom{T_m - T_s}{T_r - i}}{\binom{T_m}{T_r}}$$

$$E(b_{(s,r)}) = \sum_{i=0}^{\min(T_s, T_r)} i.P(b_{(s,r)} = i)$$

4. Estimated bandwidth with RTS/CTS

When the RTS/CTS handshake is used, a communication taking place between *s* and *r* defers other communications in the neighborhoods of s and r until the ACK frame is transmitted. This way, RTS/CTS mechanism enhances the medium synchronization effect, as only a relatively small amount of time needs to be simultaneously free at both ends for the communication to take place. Still considering a uniform random distribution of uniform random distribution of the medium occupancy, the available expected bandwidth $E(b_{(s,r)})$ can be evaluated using the following formula.

$$E(b_{(s,r)}^{rts}) = \sum_{i=0}^{\min(\tau_{m},(\tau_s+\tau_r+1))} \sum_{j=0}^{\min(\tau_s,i-1)} \sum_{k=0}^{\min(\tau_r,i-1)} (\min(\tau_s - j, \tau_r - k).p(i,j,k))$$

5. Cross layer parameters for routing

In [9], cross layer architecture is proposed with different parameters at different layers. More optimized algorithms can be design by allowing Physical and MAC layers to provide information to Network and transport layers regarding.

The different layers and the associated parameters are given in Figure 3.
These different parameters can be intelligently exchanged in multi-hop wireless networks to select a route which has:

- More link life, good signal strength, less interference and noise ratio
- Less media access delay, more bandwidth and throughput
- Less congestion

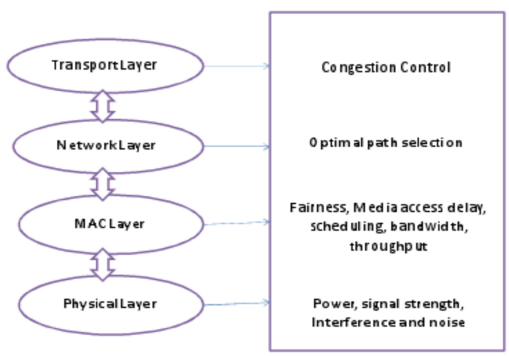

Figure 3. Different layers and associated Parameters

Such kind of parameters needs to be considered before the design of any routing protocol for multi-hop wireless networks. Most of the current routing protocols such as AODV, DSR etc select the shortest path between source and destination. Now, the issue is, if this shortest path has such intermediate nodes having less battery power, more delay, less bandwidth, high congestion, and more noise ratio. In such cases, the path is not optimal for long and bandwidth-oriented transmissions such as multimedia or real time applications; as such applications need more bandwidth, less delay and more link life. An adaptive and optimal route can only be designed using cross layer approach, in which the source and destination select route on the basis of many parameters form different layers. An application specific adaptive routing protocol can also be devised for multi-hop wireless networks. However selection of appropriate parameters and information exchange amongst different layers is a challenging research issue.

Cross layer protocols perform well as compared to traditional. The comparison of On-Demand Link Weight (ODLW) [3] and AODV [4, 5] is given in this section. AODV is one of the benchmark routing protocol for MANET. AODV keeps one-hop information in the routing table and select the shortest path between source and destination. The metric used is hop count in AODV. On the other hand, ODLW is a cross layer routing protocol, in which the path selection is based on link weight parameters such as high bandwidth, minimum delay and more battery power. Furthermore, the route selection process is adaptive in nature, keeping in view the requirements of applications. Route discovery efficiency is very important factor, and the comparison of ODLW and AODV is given in Figure 4. This factor shows how long the routing protocol takes for discovering a certain route from source to destination. AODV has a lot of acknowledgement packets as compared to ODLW, so routing time is significant larger than the ODLW.

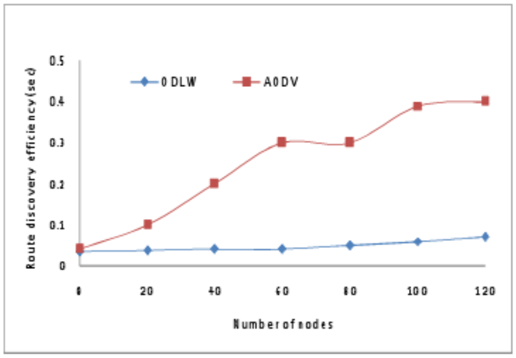

Figure 4. Route discovery time (7-sources, 120-nodes)

The next parameter that is under consideration is the effect of increasing traffic on the routing overhead as shown in Figure 5. AODV has more routing overhead as compared to ODLW due to a lot of hello messages and acknowledgements.

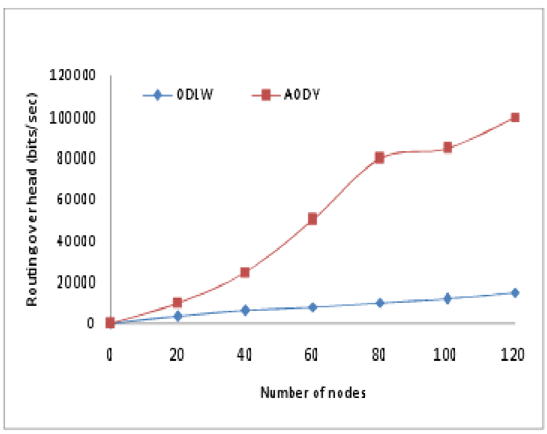

Figure 5. Routing overhead (7-sources, 120-nodes)

The comparison of AODV and ODLW is given in Table 1.

Table 1. Comparison of ODLW and AODV

	ODLW	AODV
On-demand route selection	Yes	Yes
Alternative route	Yes	Yes
Network size	All sizes	Large
Routing path	Adaptive	Shortest
Link reliability	Yes	No
Network load	Low	High
Routing overhead	Low	High
Application adaptive	Yes	No

Conclusions

Efficient and robust routing mechanism in multi-hop wireless networks is a challenging task. Routing protocols in multi-hop environment must consider some parameters such as path life, path bandwidth, link delay so that to adaptively select the most optimal path. Cross layer design is the only possible way to cope with multilayer adaptive routing protocol.

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