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# A Study of Transport Protocols For Wireless Ad Hoc Networks

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***Abstract:*** ***Ad hoc network is infrastructure less. Each individual node in an ad hoc network must be capable of acting as a host and as a router. The benefits of ad hoc architecture leads to self-reconfiguration and adaptability to highly variable mobile characteristics such as power and transmission conditions, traffic distributions, and load balancing. These benefits come at a cost. Randomness of network topology due to node mobility in ad hoc networks create new challenges, which, together with the local broadcast capability, causes a set of apprehensions relating to medium access control protocol issues, routing and forwarding issues, transport protocol issues and security issues.***

***Index Terms:*** ***Transport Protocol, MAC, Routing, TCP, Security***

## I. INTRODUCTION

There is a need for information getting shared spontaneously even in the absence of any predefined network infrastructure. For example, sharing of documents among the participants of a meeting, diversion of email from laptop to PDAs etc. On the other hand, there are certain situations where there is no scope or time for setting up an infrastructure to create a network. For example, Battle field, flood, earthquake, disaster etc. To ensure service and flow of information in such emergencies requires infrastructure less instant services. There lies the importance of ad hoc networks. An ad hoc network is defined as a temporary network. It comprises of autonomous nodes capable of self-organizing and self-managing the entire network without the need of a predefined infrastructure. It has gained immense popularity and is largely used for personal use viz. personal area network, in- house digital network etc. The nodes in ad hoc network have transmission range up to hundreds of meters. Each individual node must be capable of acting as a host and a router. At the same time the criteria of mobility in ad hoc networks has introduced certain new constraints in design which has posed challenges in effective deployment of the technology.

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## DIFFERENCE WITH CELLULAR NETWORK

The traditional cellular network model supports single hop wireless connectivity to the wired network. Installation of base station and access point are the essential criteria for a cellular network. The communication between two mobile nodes is entirely dependent on the wired backbone and the fixed base station from which the mobile node is only one hop away. The space in a cellular network is divided into cells which contains a base station responsible for communicating with the hosts in its cell.[1]

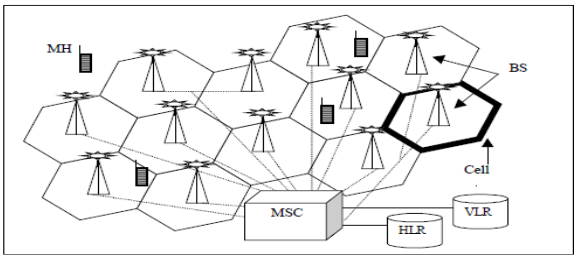


**Figure1. Cellular Network**

The significance of ad hoc network is its infrastructure less architecture. The backbone infrastructure is not available at times and setting up of access point is not viable even. The group of users still need to communicate for exchanging information. So the situation lacks any predefined infrastructure where communication is carried out via wireless ad hoc networks. Ad hoc networks does not necessarily use pre existing infrastructure and are formed with wireless hosts which are mobile in nature. In contrast to single hop architecture of cellular network, the nodes in ad hoc network posses multiple hops between the nodes. [1]The packets may need to traverse multiple links to reach destination as the route changes frequently due to mobility.

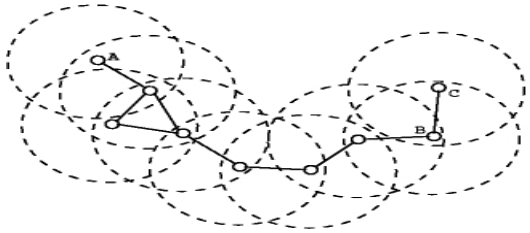


**Figure2. Ad hoc Network[1]**


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| Cellular Network | Ad hoc Network |
|---|---|
| • Network topology has a static backbone | • The Network topology is dynamic |
| • Area is divided into cells which contains base stations for communication. | • Area is not divided into cells containing base station |
| • Harmless and stable environment | • Hostile environment and sporadic connectivity. |
| • Detailed Planning is involved for the installation of base stations | • No planning required. Automatic and adaptable network formation. |
| • Higher Setup Time | • Less Setup Time |

## II. CHALLENGES IN ADHOC NETWORKS

### A. *Media Access Control*

Well known limitations of Media Access Control protocols are hidden terminal and exposed terminal problems. [2]

A hidden terminal problem takes place when two or more terminals fail to detect each other's transmission as they are out of each other's transmission range but the transmission of the two terminals are not disjoint.

An exposed terminal problem occurs in a different scenario. In this case a permissible transmission is delayed due to some unusual activity in transmission between two other mobile station which are in the range of transmission of the sender.[2]

Media access control are of two types : random and controlled. In the first case all the stations randomly competes for a channel causing inevitable collision. In the later case the completion for a channel is controlled by a master node in most of the cases where collision can be avoided. The random access method suffers from both the hidden and exposed terminal problem.

### B. *Challenges for MAC protocol in a Wireless Ad hoc Network*

- Hidden Terminal Problem
- Exposed Terminal Problem
- Throughput and Delay in transmission
- Energy Efficiency
- Fairness in channel allocation
- Ability of Multimedia Support

### C. *Proposed Solutions*

- An efficient MAC protocol named eMAC is proposed in [3] where network resources are not wasted for unsuccessful effort of connection establishment. The protocol uses an adaptive unreachability reporting mechanism along with double hop neighbor hood graph to reliably inform the stations about the unreachable status of their neighbors. The protocol has shown better performance regarding heterogeneous power distribution among contending stations and handling unreachability thus increasing the energy efficiency.

- The hidden terminal problem and exposed terminal problem has been addressed efficiently in [4]. A busy tone based MAC protocol which supports data/voice traffic is used to resolve the problem. Two separated narrow band channels having different ranges for career sensing is used to propose the solution. The fairness problem in a non fully connected environment is also improved as there is no need of extra information exchanges among the nodes in this protocol. The use of transmitter busy tone in the process of node backoff ensure the priority access for delay sensitive voice traffic and over data traffic.

### D. *Routing in Ad hoc Network*

Routing in ad hoc networks is highly unpredictable. Mobile nodes are dynamic in nature which results in frequent changes in network topologies. [5]Multi hop communication is required for ensuring effective transmission among the nodes. Routing protocols are of two types, viz., proactive and reactive. Routing information is updated periodically in table driven proactive routing protocol where every node maintains a routing table to keep the information of the known nodes. In reactive routing route is formed in an on demand basis scenario. Proactive routing is always a better solution as the route is always known and it ensures shorter end to end delays. But it has more overhead in terms of consumption of resources . The reactive routing on the other hand has much less overhead which is a major advantage for ad hoc networks. But the main disadvantage for reactive routing is its relatively longer delay as it sends the route request (RREQ) and receives the route reply(RREP). Suitable routing algorithm for ad hoc networks must be simple and easy to implement and the route convergence must be rapid. It should be distributed but lightweighted in nature with


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efficiency in less power consumption. It must be secure and scalable and should support the QOS.[5]

*E. Challenges in Routing are*

- Delay in transmission
- Slower Route Convergence
- Efficiency in power consumption
- Scalability
- Security
- Quality of Service
- Dynamic nature of ad hoc network
- Decentralized control

*F. Proposed Solution*

- The scheme proposed in [6] for efficient routing in ad hoc network guarantees_stochastic end-to-end delay instead of average delay guarantees for delay sensitive bursty traffic. The proposed mechanism selects routes based on a geographical on-demand ad hoc routing protocol and it uses traffic source and link layer channeling model to check the availability of network resources. Simulation results have shown that the proposed solution is able to satisfy the end-to-end delay bound to a probabilistic limit.
- Protocol efficiency plays a crucial role in designing effective routing protocol for ad hoc networks. The solution proposed in [7] has focused upon low additional control overhead and less power cost. The bandwidth and power constrained characteristics of ad hoc network makes the prior two issues crucial in protocol design. The proposed solution is an AODV improvement protocol in which the Hello message mechanism is presented based on wireless link availability prediction. The simulated results has shown significant performance improvement compared to standard AODV in terms of latency and protocol efficiency.

*G. Transport Protocols in Ad hoc Networks*

TCP is an effective connection oriented protocol mainly designed for fixed network. But Ad hoc networks assume TCP on the top of the networking protocols. TCP uses packet loss to indicate congestion in a wired network as the error rate is much lower there. But in case of ad hoc network packet loss is caused due to dynamic topology, frequent link failure etc and not from congestion. This results in inappropriate invoking of back off mechanism which reduces bandwidth and increases delay in the network. Asymmetric links and delayed acknowledgement are caused by variable link capability affecting the congestion window adjustment. On the other hand MAC layer provides link level reliability. TCP performance can be adversely affected by the error control mechanism used in MAC layer. If the TCP data packet and the TCP acknowledgement packet can collide to degrade the performance in TCP in a scenario when window size is greater than 1 packet. [8]

*H. Challenges in TCP for Ad Hoc Networks*

- Lossy Channels
  Signal Attenuation
  Doppler Shift
  Multipath fading
- Hidden and Exposed Station
- Path Asymmetry
- Network Partitions
- Route Failures
- Power Constraint

*I. Proposed Solution*

- Ensuring reliable transmission and recovering packet losses is an important criteria for transport protocols in ad hoc networks. The solution proposed in [9] addresses these issues effectively. It has analyzed two key functions of TCP to guarantee delivery, viz., additive increase multiplicative decrease congestion control and cumulative acknowledgement. But these two functions causes inefficiency of TCP in case the TCP connections have very small bandwidth-delay products (BDPs) and there are frequent packet losses in the network. A datagram oriented end to end reliable approach has been proposed where two techniques are highlighted viz. a fixed-size-window-based flow-control algorithm and a cumulative bit-vector-based selective ACK strategy. The transmission window has been optimally determined for a chain of n- hop and is computed to be the BDP of the path plus 3. The simulation results of the protocol shows substantial improvement in throughput, round trip time, number of retransmission and IP queue size of network performance.
- Congestion is a major problem when sensor nodes are densely distributed or a burst of a mass of data flow is. A new congestion control scheme is proposed in [10] named Phase-Divided TCP (PTCP) to control congestion through phase divided adjusting of the growth rate of the TCP window in the slow-start. The simulation results reveals significant results to resolve the problem of congestion control and improved TCP performance.


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*J. Power Conservation in Ad hoc Network*

Every node has to co -operate and participate to maintain the network connection in an ad hoc scenario. The lifetime of the network is needed to be maximized. A greedy node which remains in sleep state in majority will increase the lifetime of the battery but will remain silent in case of routing and forwarding which compromises the lifetime of the network. This process will not be helpful in forwarding and routing though it saves battery life. [11]

*K. Challenges in power conservation for Ad hoc networks*

- Limited Energy
- Constraints in battery replacement
- Decentralized co ordination
- Limitations in battery source
- Problem in selection of optimal transmission power

*L. Proposed Solutions*

- The solution proposed in [12] is based on topology control, which retain energy by either reducing the transmission power for each node or by preserving energy-efficient routes for the whole network. The protocol intelligently decides between two options, viz. whether to support energy-efficient routing or to conserve its own energy. The broadcast power of the beacon messages can be drastically reduced by this protocol. The results of the experiment has shown remarkable reduction in total energy consumption for each successfully transmitted packet and prolonged lifetime of nodes in high mobility environment.
- Energy is consumed in ad hoc networks as every node overhears every data transmission in its jurisdiction. So energy is consumed without any reason in these operations. No overhearing can also degrade the performance of the routing protocol. An efficient protocol named Randomcast has been proposed in [13] in which the desired level of overhearing can be specified by the sender that makes a balance between the energy and routing performance. It also reduces redundant broadcasts to ensure more energy savings. Simulation results shows its energy efficiency in terms of energy consumption, energy goodput and energy balance.

*M. Security Issues in Ad hoc Network*

The communication in ad hoc network is mainly via the open and shared wireless broadcast channel. So the nodes become more vulnerable to security attacks. There are a huge number of possible attacks which includes denial of service attack, passive eavesdropping, signaling attack, flow disruption attack, resource depletion attack, data integrity attack etc. The infrastructure less scenario in ad hoc network lacks the centralized security control. So security factors have become a major challenge in ad hoc networks. [14]

*N. Security Challenges in Ad hoc Network*

- Resource depletion attack
- Flow disruption attack
- Denial of service attack
- Passive eavesdropping
- Signaling attack
- Data Integrity attack
- Stolen device attack

*O. Proposed Solution*

- In [15] a robust security measure has been proposed for ad hoc networks. The protocol is named as randomly shifted certification authority authentication protocol. A trusted third party is employed by this protocol to hold the public key for authentication purpose and acts as a certification authority. The authentication protocol proposes dynamically formed short lived random clusters which has no prior knowledge of cluster head. This is done in compliance with the dynamic change in topology which changes the trust relationship among the nodes
- Deployment of ad hoc networks require specialized security services. The mechanism proposed in [16] has highlighted self certification as an essential criteria for security service in ad hoc networks. As the connectivity is unstable in ad hoc scenario an ideal protocol should interact minimally with the nodes. Furthermore due to resource constraint in ad hoc networks the protocol must be efficient in terms of computation and communication. The proposed scheme is power aware and fully non interactive self certification protocol based on bivariate polynomial secret sharing and a non interactive threshold signature scheme. The results has shown significant improvement when compared with previous mechanisms.

*P. QoS in Ad hoc Networks*

The dynamic nature of the ad hoc network as well as lack of infrastructure makes the QoS a challenging issue in ad hoc networks. Frequent changes takes place in network topology makes it very difficult to control end to end delay, jitter and packet


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loss .Guarantee of QoS is hard to achieve in dynamic environment. End to end QoS resource guarantee is only possible with the co operation of all the layers. So the challenge is to find out a solution for the Qos of all layers collectively instead of searching for individual layers. [17]

*Q. QoS challenges in ad hoc network*

- MAC related issues
- Dynamic physical link properties
- Routing
- Link state characteristics
- Power Consumption
- Dynamic topologies

*R. Proposed Solution*

- A novel QoS architecture has been proposed in [18] that can address issues regarding bandwidth, delay and jitter. The modular architecture allows plugging in different protocols to offer greater flexibility. It ensures the co operation of different protocol layers involved. The protocol optimizes interactions between MAC, routing and admission control layers to offer important performance improvement. The proposed architecture is validated in scenarios with different network loads, degrees of node mobility, and routing algorithms to quantify the benefits offered.
- A QOS routing algorithm has been proposed in [19] named QOS AODV. Here more number of metrics along with more number of hops are included in addition to AODV and the weight function is given using several parameters. The protocol selects optimal route to offer QOS. Simulated results show increased throughput and decreased delay and number of hops along with decreased route discovery time.

## III. FUTURE SCOPE OF RESEARCH

Significant researches are going on to overcome the limitations faced for the various challenges in an ad hoc network. It has been observed that maintaining mobility only on lower layers up to the network layer is not adequate to provide mobility support for application. Most of the application have to rely on transport layer. This led to concentrate and identify the issues of transport protocols as a huge area of research ensuring an end to end reliable delivery via an unreliable route by overcoming the issues like multipath fading, signal attenuation, partition in network in a power constrained environment.

Designing an efficient transport protocol is a unique challenge because of the following issues:[20]

*A. Mobility-induced disconnection and reconnection*

Sender and receiver in a transport protocol can remain in different partition for several seconds at a time. This can lead to disconnection and if TCP is used as a transport protocol then the sender's packet is dropped continuously and it wrongly assumes congestion in the network whereas the actual reason being route failure. As TCP cannot distinguish between the two scenarios it leads to difficult reconnection.

*B. High out-of-order delivery ratios*

This scenario can have two different categories. In the first case out of order delivery takes place because of retransmission due to packet losses. In the second case it is because packet sent earlier arrives later than a subsequent packet.

*C. Channel errors*

Wireless channels are open and are very much error prone due to several interference caused by electric pulses or atmospheric conditions. Packets can be corrupted due to channel error in ad hoc communication.

*D. Network Congestion*

Congestion can occur in an ad hoc network if the packet buffers of the ad hoc node is filled and it cannot forward the packet fast enough compared to its receiving rate.

The effective design of transport layer protocol for an ad hoc network requires the fulfillment of the following essential conditions:

- Maximized throughput for a connection.
- The throughput fairness should be provided.
- Minimized Connection setup time.
- Minimized Connection maintenance overhead.
- Mechanisms for congestion and flow control.
- Ensuring reliable and unreliable transport.
- Efficient use of available bandwidth.
- Awareness of resource constraints, e.g., power and buffer size.
- Efficient use of lower layer information for improved performance.
- Efficient, scalable and protocol independent cross-layer interactions.

TCP is the main transport layer protocol which is given maximum priority by the ad hoc network. But the design of TCP has been carefully implemented for wired environment. There is a requirement to propose an entirely new transport protocol to increase its efficiency for improved performance in the transport layer of ad hoc


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networks to properly asses the reason for packet loss without invoking unnecessary delay.

## IV. CONCLUSION

The paper discusses about the significance of wireless ad hoc network in present context. At the same time it has pointed out the major limitations faced in an ad hoc environment that require attention. It has discussed the proposed solutions that have been put forward to combat the challenges. Finally the paper has concentrated upon the area of interest for future work in ad hoc network. The concluding portion of the paper has shown interest to work with the efficiency of transport protocol to ensure reliable end-to-end delivery. Future research scheme will be based on the effective deployment of the conceived ideas to design a robust transport protocol for ad hoc networks.

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