A Survey of TCP over Mobile ADHOC Networks

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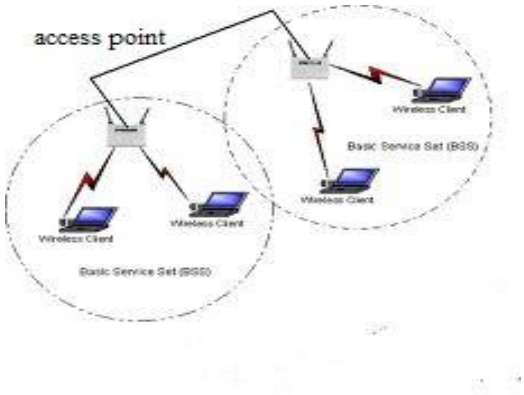
Abstract: TCP, Transmission control protocol which is mainly used in the wired network to provide process to process or end to end delivery of data. This protocol is mainly known because of its feature of providing a reliable delivery of packets from source to the destination due to this capability researchers are always interested in deploying it over Mobile Adhoc Networks but while deploying TCP on MANET they faces many problems. To overcome these problems, lots of variants and improvements had been proposed and a lot of work is going on. In this paper we just try to first put some light on the various issues faced while deploying TCP over MANET and then some of the improvements techniques proposed so far.

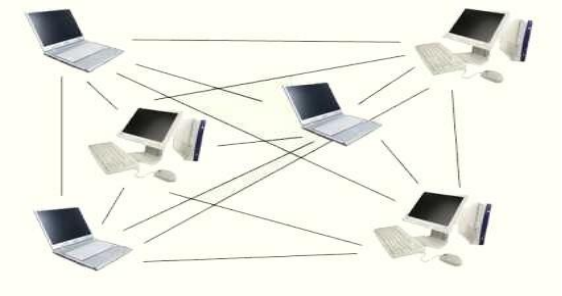
Index Terms: Mobile Adhoc Networks, Transmission control protocol, Mobility, Destination-Sequenced Distance-Vector, Wireless Routing Protocol, TCP Feedback, TCP Explicit Link Failure Notification, TCP Detection of Out-of-Order and Response

1. Introduction

Computer Networks in which the interconnection between different computers (nodes) is not with the help of wires are called as Wireless Network. These Networks are in great demand now a day's because of the fact that the initial setup cost of the network is reduced significantly. They can be broadly classified as Infrastructured network and infrastructure-less networks. Infrastructure networks are the networks in which some kind of Central controlling device (also called as the access point or router) is needed to control and monitor the entire network. This device is also responsible for performing all the necessary functions like routing the packet from source to the destination, maintaining flow control error control across the network etc. On the other hand infrastructure-less networks are the networks in which no central controlling devices is needed and the nodes itself are responsible for performing the function of the controlling device. These two types of networks are shown in the figure 1.1.



Infrastructured network



infrastructure-less network

A wireless ad-hoc network is a type of infrastructure-less wireless network, i.e it lacks any pre-existing infrastructure such as routers in the case of wired networks and access points in the case of wireless networks. In this, each node participates in the routing function by forwarding packets of data for other nodes. These types of networks are formed by multiple nodes interconnected with the help of a wireless link. The links between any pair of nodes are influenced by the nodes resources and by the link properties which includes length of link noise etc.

These networks can be further classified on the basis of application as

- Wireless mesh networks
- Mobile ad-hoc networks
- Wireless sensor networks

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A mobile ad-hoc network (MANET)is a self-configuring wireless network that consist of different nodes which may be static or mobile in nature connected through a wireless link. Each node in these type of network is free to move in any direction, and thus will change its links with other devices repeatedly. They also act as a router by forwarding packets that are not addressed to them. MANETS can also be of various types like Vehicular Ad-hoc network (VANET) which are formed between vehicles and various roadside equipments, Internet based Ad-hoc networks (iMANET) that links various mobile nodes with the fixed gateways of the internet. A simple example of MANET is shown in figure 1.2

As shown in the figure different nodes forming the network are mobile that is they are free to move or we can say they are free to either leave or join a particular network which results in a very dynamic topology that changes very rapidly and unpredictably. These types of networks are mainly used in the communication by the Soldiers either in a War situation or in a situation of rescue. They are also used as a replacement for the permanent Infrastructure network in the case of natural disasters like earthquake and flood. The main challenges faced while deploying MANET is equipping each node with some special type of hardware or software so that it can maintain the route information properly and thus help in routing a particular packet from source to destination. As the nodes in MANET are mostly mobile, maintaining correct route information is a crucial task. As all the mobile nodes are mobile and work on battery power, maximizing the use of these resources should also be taken into consideration. An example of MANET is Bluetooth.

2. Routing in MANET

Routing can be defined as a way of selecting path in a network through which all the packets will move from its source to the destination. In the case of Infrastructure networks the central controlling device stores all paths (route) from different source to the different destination but in Ad-hoc networks each node maintains the route from source to destination routing protocols specifies the way in which Routing is performed. In MANET they can be broadly classified into 3 categories

1. Based on Topology
2. Based on Location

2.1.1 Topology based approach

This technique uses the knowledge of instant Topology of the network. The routing protocols related to this are again divided into thre0e categories

1. Proactive Routing Protocol
2. Reactive Routing Protocol

2.1.1.1 Proactive Routing Protocols

These protocols are derived from the traditional approach of routing. the basic idea is each node maintains a table called as routing table that stores the path to every other node. In these routing protocols route updates are propagated at a regular interval of time regardless of the mobility and traffic characteristics of the network. The main advantage of this approach is due to periodic updates routes are always available whenever they are needed. on the other hand the main disadvantage is the overhead in storing such a details in large networks. Routing protocols that comes under this head are DSDV (Destination-Sequenced Distance-Vector), WRP (Wireless Routing Protocol), OLSR (Optimized Link State Routing Protocol) and FSR (Fisheye State Routing).

2.1.1.2 Reactive Routing Protocol

This is a very different approach of routing in which a route from source to destination is only discovered when it is actually needed. Whenever a particular node wants to send data to another node, routing tables are checked to verify that the route exist or not if no route is available route discovery procedure is called in order to find out a route from the sender node to the destination node. Once the route is discovered it remains until the destination node is inaccessible or the desired route is no longer needed. Due to this these types of protocols are also called as on demand routing protocol. The main advantage of this approach is overhead is reduced drastically. The drawback of this approach is extra latency is needed in the route discovery method this Latency is also called as acquisition Latency. [8]. This approach mainly includes three types of routing protocols i.e. DSR (Dynamic Source Routing protocol), AODV (Ad hoc On-demand Distance Vector protocol), and TORA (Temporally Ordered Routing Algorithm).

2.1.1.3 Hybrid Routing Protocols

Hybrid protocols, as the name only specifies is the combination of both proactive and reactive routing protocols. ZRP (Zone Routing Protocol) which is a modular protocol is an example of such type, it divides the topology into different zones and seek to utilize different routing protocols within each zone and between the different zones based on the various properties of these protocols. The size of the different zones can be defined by a parameter r telling the radius of a zone in terms of number of hops. Intra-zone routing is done by a proactive protocol since these protocols

2.1.2 Location based approach

This approach uses the geographical position of nodes for make the routing decision. This information can be obtained through GPS or by some other mechanism. Location-aided routing (LAR) is one of the examples of this type. The route discovery procedure in LAR is: The source node puts the

location information of itself and the destination in the routing request packet. Then routing request packet is broadcast within the request zone. On receipt of the route request packet, the destination sends back a route reply packet which contains its current location If LAR fails to find the route to the destination due to estimation error or other reasons, the routing protocol resorts to flooding of routing message throughout the MANET. Now moving on to the transport layer functionalities of a node in MANET, The protocols that can work on the transport layer are UDP (User Datagram Protocol) and TCP (Transmission Control Protocol). Out of these two UDP is a connectionless protocol that provides a non reliable delivery of packets from source to the destination on the other hand TCP is a connection oriented protocol that provides a reliable end to end delivery of packets from source to the destination. This reliability is achieved by TCP by retransmitting each and every lost packet i.e. the packets will be retransmitted if the sender node does not receive an acknowledgement of the send packet within a certain interval of time. TCP was mainly invented for wired networks which are highly reliable thus TCP always assume that any type of packet loss is due to congestion in the network and thus proper congestion control mechanisms were invoked in order to cope up with that situation. Due to these advantages TCP has become one of the most important transport layer protocols that are used in most of the internet applications. Now in order to interconnect wireless networks or MANET with the already established wired internet it is important to make TCP work in the wireless environment also now to deploying TCP in wireless we first need to understand the functioning of TCP in wired networks. To provide a guaranteed end to end, reliable, ordered delivery of packets from a particular source to destination the basic functionalities like error control, flow control and congestion control are very essential. Also a three way handshaking protocol is used in order to ensure that a particular packet reaches its destination and in its correct order. For achieving flow control a sliding window protocol is used, in this protocol three types of windows are defined Transmission Window, Congestion Window, and Advertised Window. Transmission window specifies the Maximum number of packets a particular sending node can send without reception of any acknowledgement from the receiving node. Congestion Window specifies the maximum number of packets that a particular sending node can send without congesting the network. This number is specifies from the sending node by the feedback in gets about the network condition at a particular point of time. Advertised Window specifies the amount of data receiver is ready to receive or the receiver is expecting in the near future. The size of this window is specified by the receiver depending upon the buffer size at the receiver end. Another technique used by the TCP to minimize the network load is the concept of cumulative acknowledgement. This basically means that a common acknowledgement for a particular number of packets will be send and on the receipt of that cumulative acknowledgement the sending node can be sure that all the previously transmitted packets with the sequence number less that that of the acknowledgement are received successfully.. Out-of-order packets are identified with the help of sequence number and for that a duplicate acknowledgement is generated and sent back to the sending node. For wired networks an out of order delivery is mainly due to packet loss and it is assumed that this packet loss is mainly due to congestion and thus congestion control mechanism are invoked, which in turn is based on sliding window mechanism and consists of two main parts slow start and congestion avoidance.

Problems Faced while deploying TCP over MANET

If we want to deploy TCP over MANET we have to face a number of issues these issues can be broadly classified under the following heads

Channel Errors:

The main causes for errors in the channel are signal Attenuation, Doppler's Shift, and Multipath Fading. Signal Attenuation can be defined as the decline in the electromagnetic energy of the signal transmitted by the sender node as the distance between the sending node and the destination node increases. As a signal which is electromagnetic in nature and due to diffraction, reflection, and refraction of the signal, a fluctuation in amplitude and phase is possible also multiple copies of a signal can receive at the destination at different intervals of time. To overcome these errors ARQ and FEC techniques are used.

Path Asymmetry:

The wireless link between any mobile node and a base station is asymmetric in nature. This asymmetry can be of three types' bandwidth, loss rate, and route. Bandwidth asymmetry defines the different types of symmetry between the base station and the mobile node. Mostly the base station are reliable and have high bandwidth as compared to that of the mobile node which is error prone and have a limited bandwidth thus becoming a bottleneck for TCP. An example of this is the Bandwidth of typical lan can vary from 100Mpbs to 1 Gbps or more on the other hand the bandwidth in a typical 3 G network is maximum of 7.2 Mbps.

Mobility:

Mobility feature provided to the nodes come with some advantages as well as some disadvantages to. The main advantage of this feature is allowing the node to move within a particular region and disadvantage include increase in overhead as mobility causes link breakages (which can be defined as breaking up of s link between a pair of nodes), route failure (when a link is disconnected the route from source to destination also goes down thus causing route failure), and network Partition (if we assume the whole topology as a graph with the nodes of the graph representing the various mobile nodes of the topology and an edge between two nodes represents a link between them then network partition occur if the graph is disconnected) between two nodes which in turn causes packet loss. The reestablishment of route from source node to the destination node depends on the factors like Routing Protocol used, Traffic Characteristics of the network and Mobility Pattern of the Mobile Nodes.

Congestion:
As Known TCP is a violent Transport Layer Protocol that attempts to utilize the network resources to its fullest, this feature makes an MANET easily undergoes a situation called as Congestion. This Congestion in turn causes overflow of the buffer and increase in the link conflict thus degrading the overall performance of TCP.

Power Constraints:
As known mobile nodes works on battery power which is limited, which means that the processing power is also limited also each node is acting as an end node as well as a router at the same time therefore a successful energy scheme must be applied to utilize the resources to its maximum. This can be easily done by minimizing the number of transmission which are not needed.
Two techniques can be applied energy conservation and energy consumption.

Solutions for Deploying TCP over MANET

Lots of efforts has been done in order to improve the performance of TCP over MANET. A total of 12 different TCP variants and 7 improvement techniques had been proposed so far.
Some of the variants are:-

TCP-F: (TCP Feedback) [2] this technique is based upon the feedback given by the intermediate nodes to the sending nodes which allows the sending node to differentiate between the congestion and route failure. Two types of special packets are used in this technique RFN (Route failure Notification) on receipt of this packet the sending node goes into sleep mode and the restoration of sending packets start on the receipt of RRN (Route re-establishment Notification).

TCP-ELFN: TCP (Explicit Link Failure Notification) [3] This technique is similar to TCP-F. In this technique an ELEFN message (on route failure) is sent by the routing protocol to the sending node. On receipt of this message the sending node enters the standby state and stops the transmission of packets. A periodic probe message is sent to check whether the route is now available if probe packet is successfully delivered the sending node leaves the standby state and starts sending the packet again.

ATCP: (Ad hoc TCP) [5]) This technique also uses the feedback about the network from the intermediately nodes.. In addition to finding out the route failures, it also tries to deal with the problem of high Bit Error Rate. In this technique the sending nodes can have any one of the following three states persist state, congestion control state and retransmit state. An extra layer called ATCP is inserted between the TCP and IP layers of the general OSI model. Two special types of messages are ECN (Explicit Congestion Notification) messages and by ICMP "Destination Unreachable" message are used to decide the state of the sending node.

TCP-Bus: This technique introduces the introduction of buffer memory in the mobile nodes. It also uses the feedback from the intermediary nodes with little enhancements. Two special messages ERDN (Explicit Route Disconnection Notification) and ERSN (Explicit Route Successful Notification) are used to notify the sender about the current status of the route. Pivoting Node id the node that detected the route failure called the. During the Route Re Establishment phase packets from source to the PN are buffered also timer value for buffered packets is doubled in order to avoid the timeout.

Fixed RTO: [8] This is a sender-based technique that does not rely on feedback from the network. Whenever the missing ACK is not received before the second RTO expires, a route failure event is concluded. The unacknowledged packet is retransmitted but the RTO is not doubled a second time. The RTO remains same until the route is re-established and the retransmitted packet is acknowledged.

TCP DOOR: (TCP Detection of Out-of-Order and Response) [7].This techniques used as an alternative to feedback approach for improving TCP performance over TCP. In this out-of-order (OOO) delivery events are identified at both the sender and receiver node. Basically OOO can only occurs when a packet sent at earlier time arrives later than a succeeding packet. In This condition can happen many times in MANET due to mobility which cause change in path from source to destination. For detecting OOO, ordering information is added to the data packets and TCP ACKs. T he sender node detects the OOO ACK packets and the receiver detects the OOO data packets.

Split TCP: [9] Split-connection approach makes TCP works in wireless network by splitting the TCP Connection into two parts at the base station. This scheme includes two techniques I-TCP (Indirect TCP) and M-TCP. Indirect TCP is used whenever a mobile node wants to communicate with a fixed node. In this case the TCP connection is breached into 2 parts one between the mobile node and between the base station and second between the base station and the fixed node. Proxy based approach uses a special agent at the base station that differentiate between the packet loss and the congestion condition. Link layer solution makes changes at the data link layer.

Preemptive routing in Ad hoc networks: [10] this technique reduces the number of route failures and the latency required in route reconstruction. This is mainly achieved by switching to a new route from source node to destination node when a link of the current route is expected to fail in the future The mechanism for detecting link failure is based on power, whenever an intermediate node along a route founds that the signal power of the received packet is less than the given threshold value, then that route is about to break as that node will not be available in near future. Thus the process of switching to a new node should be started.

Signal strength based link management in Ad hoc network: This algorithm is similar to the previous one. However, in this algorithm each node keeps a record of the received signal strengths of 1-hop neighboring nodes.

Using these records, the routing protocol predicts link break event in the immediate future this prediction is called Proactive Link Management. On detecting this event, the source's routing agent is notified by a Going Down message. On receiving this message the source's routing agent stops sending packets, and Initiates a route discovery procedure. The novelty of this proposal is the Reactive Link Management mechanism. This Mechanism increases the transmission power to re-establish a broken link. Reactive and Proactive Link Management Mechanisms can be coupled in the following way: on predicting that a link is going to be down, the node's routing Agent notifies the source to stop sending, and this node increases its transmitting power to handle packets in transit That use this link.

Some other variants are TCP-JERSEY, TCP – WESTWOOD, TCP_VEGAS, TCP-RENO etc.

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3. Conclusion

We have presented the state-of-the-art of TCP over mobile Ad hoc networks (MANET).The principal problem of TCP in this MANETs environment is clearly its failure to discriminate between losses induced by network congestion and others types of losses. TCP assumes that losses are always due to network congestion this assumption is valid in wired networks, it is not true in MANETs. In MANETs, there are indeed several types of losses, including losses cause by routing failures, by network partitions, and by high bit error rates. Performing congestion control in these cases, like TCP does, yields reduced performance. In order to solve these problems, several proposals have been made in the literature. In some proposals, TCP and the underlying protocols cooperate to improve Ad hoc network performance. In other proposals, TCP require only the cooperation of the sender and receiver in order to work in the MANET environment.

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