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Data Transmission Protocol for Hybrid Wireless Networks with QoS Assurance

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Abstract— the popularity of wireless communication is increasing at a rapid rate. This has led to increased research activities in supporting real-time transmission with strict QoS requirements for wireless applications. A hybrid wireless network is an integration of mobile wireless ad-hoc network (MANETs) and wireless infrastructure networks. Guaranteeing of QoS in hybrid wireless networks remains an open challenge. If resource reservation based QoS routing is adapted directly into hybrid wireless networks, it leads to invalid reservation and race condition problems. In Adhoc networks, routing is the important phase that considerably improves the QoS. There are numerous routing protocols that are in use today. AODV (Adhoc On demand Distance Vector) is the more frequently used. In this paper, a new variant is proposed which gives better results than the AODV protocol improving the QoS with respect of a set of QoS parameters and under different constraints, taking into account the limited resources of mobile environments (bandwidth, network size etc). Here we propose a QoS-oriented data transmission technique that enhances the QoS support exclusively for hybrid wireless networks. It incorporates the following algorithms: 1) Neighbour identification and best path selection for data transfer ensuring QoS, 2) Packet scheduling algorithm among selected neighbouring nodes to further reduce the stream transmission time. All these algorithms reduce the transmission delay of data thus supporting the QoS requirement in hybrid wireless networks.

Keywords— Quality of Service; routing; hybrid wireless networks; delay; bandwidth;

I. INTRODUCTION

Numerous wireless applications have been developed in wide areas like commerce, emergency services, military, education, and entertainment. Wi-Fi capable mobile devices laptops and handheld devices are increasing rapidly day-to-day. Watching videos, playing games, TV and long distance video conferencing are the major interests for all wireless mobile device users. Therefore, video streaming applications such as Facebook, WhatsApp etc on the infrastructure wireless networks have received increasing attention recently. These applications use an infrastructure to directly connect mobile users for video watching or interaction in real time. There is a widespread use of wireless and mobile devices and also the demand for mobile multimedia streaming services are leading to a promising near future where wireless multimedia services (e.g., mobile gaming, online TV, and online conferences) are widely deployed.

This real time and multimedia applications have stimulated the need of high Quality of Service support in wireless and mobile networking environments [1]. The QoS support reduces end- to-end transmission delay and enhances throughput to guarantee the seamless communication between mobile devices and wireless infrastructures. Quality of Service (QoS) of a network is its capability to provide better service to selected network traffic over various technologies, including Frame Relay, Asynchronous Transfer Mode (ATM), Ethernet and 802.1 networks, SONET, and IP-routed networks that may use any or all of these underlying technologies. The most important goal of QoS is to provide priority with dedicated bandwidth, controlled jitter and latency (required by some real-time and interactive traffic), and improved loss characteristics. Also important is making sure that providing priority for one or more flows does not make other flows fail. The QoS support must consider a number of Ad-hoc networks constraints (mobility, energy, scale, etc.). QoS can be introduced at different layers of the network if there is need (channel access functions at MAC layer, routing protocols at network layer, etc.).[2]. Routing operation consists of finding the routes between communicating entities (transmitter / receiver) able to convey data packets continuously using less bandwidth and fewer packets control. Routing in MANETs must also manage constraints of nodes energy problems, topology frequent changes due to nodes mobility and communication channel nature (air). QoS routing can be defined as the research for routes satisfying the wanted (desired) QoS. To be as eligible routes, they must satisfy a number of constraints (such that delay, bandwidth, reliability, etc.) [3].

The routing function is the main phase of any routing protocol for any network and particularly for Adhoc networks. There are many Routing protocols under research and several variant of the protocols are proposed to achieve the QoS objective. The most quoted in literature is almost certainly the AODV protocol [4]. Ensuring routing QoS consists in determining one or several (paths) that satisfy best QoS constraints such as delay, packet loss, throughput, jitter, etc. The AODV protocol (Ad-hoc on demand Distance Vector) is a reactive routing protocol. It's based on the distance vector Principle with a combination of unicast and multicast routing. In AODV, the path between two nodes is calculated when needed (if necessary), i.e. when a source node wants to send data packets to a destination, it finds a path (Discovery Phase), uses it during the transfer phase, and it must maintain this path during its utilization (Maintenance Phase). The disadvantages of AODV are more significant which include higher processing demand, consumes more share of bandwidth, takes more time to build the routing table which increases the overall delay and performance which is undesirable in any of the networking applications.

In this paper we propose data transmission technique for hybrid wireless networks that promote the QoS consideration to a great extent. Hybrid wireless networks (multi-hop cellular networks) are the generation wireless networks and can help tackle the stringent end-to-end QoS requirements of different applications. Hybrid networks are the combination of infrastructures networks and MANETs. Specifically, infra- structure networks improve the scalability of MANETs, while MANETs automatically establish self-organizing networks, extending the coverage of the infrastructure networks. In a vehicle opportunistic access network (an instance of hybrid networks), people in vehicles need to upload or download videos from remote Internet servers through access points (APs) (i.e., base stations) spreading out in a city. Since the base stations does not cover the entire city to maintain sufficiently strong signal everywhere to support an application requiring high link rates, the vehicles themselves can form a MANET to extend the coverage of the base stations, providing continuous network connections [22]. Usually, a hybrid network has widespread base stations. The data transmission in hybrid networks has two features:

1) An AP can be a source or a destination to any mobile node.
2) The number of transmission hops between a mobile node and an AP is small.

First feature allows a stream to have anycast transmission along multiple transmission paths to its destination through base stations, and the second feature enables a source node to connect to an AP through an intermediate node. With these 2 features, QoS-oriented data transmission technique converts the packet routing problem into a dynamic resource scheduling problem. Specifically, if a source node is not within the transmission range of the AP, a source node selects nearby neighbours that can provide QoS services to forward its packets to base stations in a distributed manner. The source node schedules the packet streams to neighbours based on their bandwidth, delay that is encountered due to external factors like noise and interference and mobility, aiming to reduce transmission time and increase network capacity. The neighbours then forward packets to base stations, which further forward packets to the destination. In this paper, we focus on the neighbour node selection for QoS-guaranteed transmission.

II. NEED FOR QOS

A. *QoS considerations*

Quality of Service (QoS) refers to a set of mechanisms able to share fairly various resources offered by the network to each application as needed, to provide, if possible, to every application the desired quality (the network's ability to provide a service).

The QoS is considered to have a certain number of parameters (throughput, latency, jitter and loss, etc.) and can be defined as the degree of user satisfaction. QoS model architecture is designed to provide the possible best service. The model must handle all the constraints and challenges imposed by Ad-hoc networks, like network topology change due to the mobility of its nodes, constraints of reliability and energy consumption, so it describes a set of services that allow users to select a number of safeguards (guarantees) that govern such properties as time, reliability, etc. [5][6]. Classical models like Intserv / RSVP [7] and DiffServ [8] proposed in first wired network types are not suitable (adapted) for MANETs which requires node negotiation, admission control, resource reservation, and priority scheduling of packets [9]. However it is more difficult to assure QoS in MANETs due to unique features like user mobility, channel variance errors, and limited bandwidth. As a result, attempts to directly take in the QoS solutions for infrastructure networks to MANETs mostly do not have great success [10]. Several reservation-based QoS routing protocols have been proposed for MANETs [11], [12], [13], [14] which creates routes formed by nodes and links that reserve their resources to satisfy QoS requirements. Even though these protocols try to improve the QoS of the MANETs to a certain degree, they suffer from invalid reservation and race condition problems [15]. Invalid reservation problem if the data transmission path between a source and destination nodes breaks the reserved resources becomes useless. Race condition problem refers to a dual allocation of the same resource to two different QoS paths.

III. AODV-ADHOC ON DEMAND DISTANCE VECTOR ROUTING PROTOCOL

A. *Introduction*

The AODV protocol (Ad-hoc on demand Distance Vector) [7] is a reactive routing protocol which is descendent of distance vector routing protocol. It provides both unicast and multicast routing. Here,in AODV, the path between two nodes is calculated whenever required, i.e. when a source node has some data to be sent to destination, it explores a path (Discovery Phase), uses it during the transfer phase, and it maintains this path during its utilisation (Maintenance Phase). The finding and maintaining process of a path is based on the exchange of a set of control packets: RREQ (Route REQuest), RREP (Route Reply), RERR (Route Error), RRepAck (Route Reply Acknowledgment) and Hello messages (Hello). Below is the importance of control packets:

1. RREQ is initiated by the source node to find a path in multicast mode.
2. RREP is used by an intermediate or destination node to respond to a request of path finding in unicast mode.
3. Hello messages are used to maintain the consistency of a previously established path.
4. RERR (Route Error Message) allows AODV to adjust routes when Nodes move around. Whenever a Node receives RERR it looks at the Routing Table and removes all the routes that contain the bad Nodes.

B. Working of AODV

AODV uses Routing table that contains the routing information for each node and has the destination address, the list of active neighbours, the number of hops (hop) to reach the destination, time of expiration after which the entry is invalidated, and so on. Formation of infinite loops is prevented by use of Sequence numbers. This also prevents the unnecessary transmission of control packets. These numbers allow the use of fresh routes following the mobility of nodes, as they ensure the coherence and consistency of routing information [16]. Sequence numbers function as time stamps. They allow nodes to compare how much recent is their information on other nodes. Every time a node transfers any message it increases its own Sequence number. Each node records the Sequence number of all the other nodes it talks to. A higher Sequence numbers signifies a fresher route. This it is possible for other nodes to figure out which one has more accurate information. It should be noted when the path breaks due to the absence of one node either by removal or a problem of energy, a local repair procedure (local repair) is called, it takes over the reconstruction of the path from this point. If this procedure cannot solve the problem, the source node try to find a new path and the number of attempts (RREQ_RETRIES) is decremented by 1, until the success or failure of the communication link. This procedure generates a considerable amount of control packets. It should be noted that the AODV maintains only one path to destination. Hence the disadvantage here is that if the path breaks it requires considerable amount of time for setting up the path again and transmission of control packets increases the bandwidth usage, delay incurred in the entire process of setting up the path and due to which the performance is highly affected. This is not the desirable feature that we are looking for the enhancement of QoS support.

AODV can determine multiple routes between a source and a destination, but maintains only a single route, because 1) it's difficult to manage multiple routes between same source/destination pair 2) If one route breaks, it's difficult to know whether other route is available 2) Lot of book-keeping is involved. In AODV, Broadcasting is done via Flooding. Flooding may deliver packets to too many nodes (in the worst case, all nodes reachable from sender may receive the packet). One undesirable effect of flooding is data packets may be delivered to too many nodes who are not the intended receivers. The disadvantages of AODV are more significant which include higher processing demand, consumes more share of bandwidth, takes more time to build the routing table which increases the overall delay and performance which is undesirable in any of the networking applications. Also invalid reservation problem adds on to the disadvantages since the reserved resources become unused in case of breakage of the established path.

IV. QOS ASSURED DATA TRANSMISSION TECHNIQUE FOR HWN

A. Overview

HWN have high mobility and fluctuating bandwidth because of which ensuring and guaranteeing of QoS remains an open problem. Even though there are many protocols that provide provision for QoS routing in infrastructure networks like Intserv[7] , RSVP[8] have additional overhead of node negotiation, admission control, resource reservation, and priority scheduling of packets.

In MANETs it's more difficult to ensure QoS due to its features of user mobility, channel variance error and limited bandwidth. Any efforts of adapting the QoS solutions for infrastructure networks to MANETs do not have great success. Number of resource reservation based protocols has been proposed for MANETs [17] [18] [19] [20] [21] that try to provide QoS, but suffer of race condition and invalid reservation problem. Even though there are efforts that try to guarantee QoS in HWN, but most of the works try to increase network capacity and reliable routing but not completely concerned about providing QoS. In this regard we propose a QoS oriented data transmission technique that ensures QoS in Hybrid wireless networks. HWN has widespread base station and the data transmission has 2 main features, one being an Access Point can be either a source or destination to any node and the other being number of transmission hops between mobile node and an AP is very small. The first feature enables anycast transmission along multiple paths and the second feature aids a source node to connect to an AP through an intermediate node. With these 2 features this technique converts the packet routing problem into a dynamic resource scheduling problem.

B. Idea of the technique

In this protocol if a source node is not within the transmission range of an AP, it selects a neighbour that is nearby packet stream from the source node to its neighbour is done based on their bandwidth, delay due to external factors like noise and interference and mobility, targeting to reduce transmission time and increase network capacity. These neighbours then forward the packets to base stations which in turn to destination. Here we propose 2 main algorithms for providing QoS in data transmission:

1. Neighbour identification and best path selection for data transfer ensuring QoS,
2. Packet scheduling algorithm among selected neighbouring nodes to further reduce the stream transmission time.

C. Neighbour identification and best path selection for data transfer ensuring QoS.

Traffic or data transmission requires short delay which is one of the major real-time requirements. In this module from a particular source to destination, the possible neighbour nodes are identified using the Euclidean distance formula. First, all the possible paths towards the destination are identified.

A node is said to be a neighbouring node if its distance from the source node is within the pre specified threshold distance value. This neighbour identification is done to all nodes in a network. With these neighbouring nodes, we need to identify potential nodes that would form a best path towards destination. For calculating potential neighbouring nodes several factors are taken into account. They are 1) Bandwidth of the neighbouring nodes, 2) External factors, 3) mobility of a node.

Now, we'll discuss in detail how all the factors would affect our neighbour node selection process.

1) Bandwidth: Bandwidth of a node plays an important role as whole identification process depends on this. Each and every node has its own bandwidth associated with it. For any data –transmission, we need to check for the available bandwidth of the intermediate nodes to get the best path. An intermediate node from the identified neighbouring nodes that has the bandwidth to transmit the data is selected. It is assured that the bandwidth of a node is at least the size of the largest packet in that data transmission stream along the path. This process of potential neighbour selection continues for each neighbour node that finally gives the path that is QoS guaranteed. Even though, there are many possible paths that are available best possible paths ensuring QoS are identified for data transmission that also consider our factors in to account. Hence, while calculating the paths, based on the parameters that we have considered and the packet arrival time there could be single path or multiple paths. This is explained in the next section.

Next parameter in our technique is the delay which is encountered due to external factors like noise and interference.

2) External factors: external factors like noise, interference play an important role for data transmission. Consider a video conferencing application; if the noise factor is too high then it does not deliver the best quality of service to customers. The entire video conference is delayed resulting in poor application performance. Hence while calculating the delay due to these factors we need to consider the minimum value from the pre specified value along the path towards the destination. The external factors would be due to more number of nodes that are transmitting data at the same time or interference or interference due to buildings or other objects on the way. A path is selected based on the low external value from among the possible paths towards destination. This guarantees QoS which reduces the overall delay for transmitting data.

The last factor into consideration for identifying the best path towards destination is mobility of a node.

3) Mobility of a node: In a highly dynamic mobile network there are more chances of link failure between any 2 nodes. This results in the retransmission of packets which in turn results in the delay which is undesirable for our QoS assurance. This delay degrades the QoS of the transmission of a packet flow. Hence for identifying the best path with QoS we consider the path in which the mobility of the nodes is small. Based on these parameters; bandwidth of the intermediate nodes, external factors like noise and interference and mobility of a node, best and efficient path that provide QoS are identified for data transmission towards destination.

Next section explains how the data packets are scheduled among the identified best paths are scheduled.

D. Packet scheduling algorithm among selected neighbouring nodes to further reduce the stream transmission time.

The first algorithm addresses the selection of neighbour nodes ensuring the QoS provision for packet transmission. To further reduce the stream transmission time packet scheduling algorithm is proposed to handle packet routing. There could be much number of paths towards the destination. But the best path is the one that consider all our parameters assuring QoS. If it's a multi path routing then data is split among multiple path. For scheduling of data packet along the best path we need to consider their arrival time at a node. If the packets all arrive at the same time then the packets are distributed from among the paths that satisfy QoS constraints. That is, the first packet is scheduled to first efficient path, second to second efficient path. This continues for the number of path that is available.

For example if there are 10 packets that arrive at a node at about 1.2ms. The 1st packet is scheduled to 1st path, 2nd packet to 2nd path and 3rd to 3rd path if there are 3 multiple paths. The fourth packet is queued to be scheduled to 1st path, 5th to 2nd path and so on. The other scenario is that if all the packets arrive at different time intervals then all the packets scheduled for transmission along one single efficient path that guarantee QoS.

The below are the advantages of our technique over AODV:

AODV suffers from invalid reservation problem. This is because the resources are reserved for the QoS traffic in each link. In a highly dynamic network, the links that are reserved frequently breakdown which in turn forces the source node to search for a new path to an AP. This path searching, results in a delay which degrades the QoS requirement. Also the race condition problem wherein the same resources are reserved for different source nodes at the same time. This makes some of the source nodes deprived of the resources when they are actually needed. These 2 problems definitely reduce the QoS throughput.

In our QoS oriented data transmission technique the resources are not reserved for each transmission link. The source node in turn schedules the packets to neighbour nodes depending on the parameters that we have discussed above. Besides, every intermediate node receives the scheduled packets for the transmission; the same scheduled resource will not be allocated to more than 1 source node at the same time which prevents the race condition problem. Additionally, the above algorithms schedules the traffic based on the bandwidth, mobility of nodes for guaranteed QoS routing.

AODV has longer path lengths than our technique. Longer path lengths means frequent link breakdown due to which the packets don't arrive at APs in time. Packet scheduling algorithm prevents race condition problems as explained earlier and packet resizing algorithm increases the scheduling feasibility of the intermediate nodes. This increases the QoS requirement when compared to AODV in a highly dynamic system.

V. CONCLUSIONS

QoS assured data transmission technique is the work dedicated to improve the QoS requirement exclusively for Hybrid wireless networks. HWN is an integration of MANETs and infrastructure network. Even though there are many routing protocols designed for MANETs or infrastructure network separately, they cannot be adapted directly into each other because of the problems discussed till now. The 2 main features of hybrid wireless networks that is, anycast transmission and short transmission hops convert the packet routing problem to packet scheduling problem. The 3 algorithms used try to achieve the data transmission by satisfying the QoS requirement to a great extent. The problem of race condition and invalid reservation problem are also avoided when compared to AODV protocol resulting in achieving greater QoS throughput.

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