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Addressing Hidden Terminal Problem in Heterogeneous Wireless Networks

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***Abstract*— Heterogeneous Wireless Networks is an emerging area. Hidden nodes are a fundamental problem that can potentially affect any heterogeneous wireless network due to the heterogeneous characteristics. The performance may degrade significantly, when use existing methods such as RTS/CTS in the heterogeneous network. In order to overcome the hidden terminal problem in heterogeneous wireless network, a new packet is introduced to incorporate the details of the other nodes within the range of the access point. This will give prior information to every transmitting node about the existence of other nodes within the range. The above idea can be simulated by using NS2. The performance analysis can be done on the basis of packet drop and average packet delivery of the proposed system in various scenarios.**

Keywords—Heterogeneous wireless networks; hidden terminal problem

I. INTRODUCTION

In the 1970's and the 1980's, computer networks were considered as fixed form. In the latest years, the proliferation of mobile computing devices, such as laptops, personal digital assistance (PDA's), or mobile phones, has led to many changes in the computer world. To communicate all those devices, a wired network is not feasible. Thereby, wireless networks is introduced. Wireless networks use electromagnetic radio waves for exchanging data.

Wireless networking is the technology which uses standard network protocols instead of network cabling for communicating with computers. The 802.11 is the widely used wireless standard, which is defined by the Institute of Electrical and Electronic Engineers (IEEE).Wireless network uses an access point or base station for providing connectivity with wireless computers. Each access point or base station has a defined range for maintaining wireless communication between client computer and access point. The actual transmission range varies with the environment.

Wireless networking can be classified into two broad types; homogeneous and heterogeneous networks. A homogeneous sensor network consists of identical nodes in terms of energy, power, capacity, transmission range, queue size, hardware complexity etc, while a heterogeneous network [1] consists of two or more types of nodes which are heterogeneous in terms of energy, power, capacity, transmission range, queue size, access mechanism etc.

The heterogeneous wireless networks have the following advantages as compared to homogeneous wireless networks. The heterogeneous network increases the reliability, spectrum efficiency, coverage. Reliability can be improved when one particular radio access technology within the heterogeneous network fails to function it may still be possible to maintain a connection by falling back to another radio access technology. Spectrum efficiency is improved by making use of radio access technology which may have few users through the load balancing across radio access technologies and coverage may be improved because different radio access technologies may fill holes in coverage that any one of the single networks alone would not be able to fill. The main issues that lead to negative effect on heterogeneous network are due to their heterogeneous characteristics. Considering the case where the network may be heterogeneous in terms power levels and thereby causing communication links of varying range. Also due to the interference caused by the high power nodes the throughput of the network may be affected.

The rest portions of the paper divided as follows: section II present the motivation and overview of the proposal, section III reviews the body of related works, section IV briefly describes the proposed concept, section V describes the simulation environment of the proposed concept, section VI describes the performance analysis and finally section VII concludes this paper.

II. MOTIVATION AND OVERVIEW

The main factors that cause negative effect on wireless networks are low packet delivery ratio and high end -to -end delays. The other factor that causes destructive effect on wireless network is the hidden terminal problem. The nodes can be categorized into two types based on the location and topology of nodes in the network, hidden nodes or non-visible nodes and non-hidden nodes or visible nodes. Hidden Terminal Problem occurs when more than one transmitter receiver pair shares a channel. In wireless network, nodes cannot hear each other due to their short transmission range. Hidden nodes cannot receive control packets, so packets are transmitted through the visible nodes regardless of any other

nodes sending packets. This situation leads to packet loss and collision. Hidden node problem becomes a serious problem due to the large distribution of nodes and the multi-hops transmission. Therefore the hidden terminal problems continue to impact the transport layer protocol performance.

A. Hidden Terminal Problem

The hidden terminal problem[11] can be illustrated by Fig. 1.The given scenario consists of three nodes A, B and C. Node A can hear Node B but not node C, as node C is not in the transmission range of A. Similarly nodes C can hear node B but not node C, as node A is not in the transmission range of C. Nodes which are located in the transmission range of other nodes can easily receive the packets. Thus node B can receive packets from both the nodes A and C. However there will be a chance of collision at node B if both nodes A and C send their packets at the same time and due to this node B cannot receive any packet successfully. According to IEEE 802.11 MAC protocol, the hidden terminal problem can be prevented by exchanging RTS and CTS control packets.

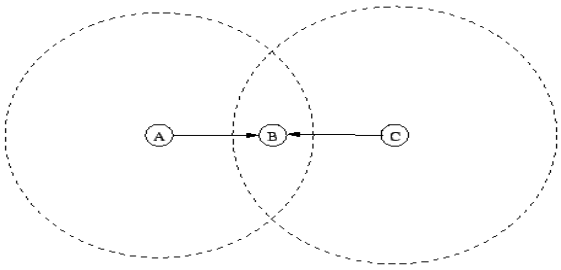

Figure. 1: Collision appearance due to hidden node

RTS/CTS (Request to Send / Clear to Send) [11] is the mechanism used by the IEEE 802.11 wireless networking protocol to reduce the collisions introduced by the hidden node problem. In this case, the sender transmits first a short RTS (request to send) control packet. It indicates the total time required to transmit the data and the acknowledgment packet. When the access point receives the RTS packet, it responds by sending a CTS (Clear to send) packet. It includes again the required time for the complete transmission. The RTS/CTS mechanism informs all stations in the range of the sender and the receiver about the planned transmission and instructs them not to send for the reserved duration. The RTS and CTS packets are short. So the collision will only last for the duration of the short packet. The following data and ACK packets are transmitted without collision. All stations in the range of the receiver are informed about the transmission and wait until it is finished. Thus the hidden node problem can be avoided.

The RTS/CTS mechanism cannot be used in heterogeneous networks due to the heterogeneous characteristics of the wireless network. The existing mechanisms cannot be adopted in the case of heterogeneous network. In order to avoid the hidden terminal problem in heterogeneous networks, a new packet is introduced by incorporating the details regarding the neighbor nodes.

III. Related Work

In the wireless networks, the nodes are distributed randomly. Based on their topology and the node's transmission range, wireless networks include hidden nodes. The hidden node has a negative effect on the throughput and performance of the wireless network. Therefore, researchers try to find mechanisms for preventing collision that occur due to hidden nodes. Some of the collision avoidance mechanisms [2] utilize control packets and monitor the status of the channel (busy or free).Some other mechanisms are based on hidden node detection and also include mechanisms which store information of the node via a coordinator or access point in order to avoid hidden terminal problem. The mechanisms for avoiding collisions can be categorized as handshake mechanism, busy tone mechanism, routing management mechanism.

Handshaking is the mechanism in wireless communication for avoiding collision in a channel. Wireless communication uses two types of channels such as data channel and control channel. The data channel is used to send and receive data and control channel is used by the control packet for managing connection. The collision of packets can be avoided by this channel division. Multiple Accesses with Collision Avoidance (MACA) [8] uses two control packets for avoiding collision occurrences. The complete exchange process or handshaking procedure involves four packets such as RTS, CTS, DATA, and ACK. RTS and CTS are exchanged over the control channel before data transmission. For reserving the medium, a sender transmits an RTS packet. After receiving the RTS packet, the destination node sends back a CTS packet. The CTS packet also contains a value related to time that alerts other nodes to hold off from accessing the medium while the station initiates the RTS to transmit its data. At the end of the RTS-CTS transfer process, the receiver sends back an ACK packet, which is a confirmation that the data was received. Multiple Access with Collision Avoidance for Wireless (MACAW) [3] introduces a new control packet. This mechanism uses an RTS/CTS/Data Sending (DS)/DATA/ACK pattern for data transmission. When Node B wants to transmit data to Node A, Node C can hear the RTS. Node C hasn't any more information about the connection between Nodes A and B because it cannot hear the CTS from the Node A. Therefore, if Node C wants to send data to Node B, it must defer this process. In order to avoiding an unnecessary deferral situation, Node B generates a DS packet as an announcement for a successful connection.

Busy tone mechanisms use control packets which are known as Busy Tones (BTs). These types of control packets are sent by the sender or receiver to their neighbors to reserve the channel during the transmission. The protocol Busy Tone Multiple Access (BTMA) is based on the RTS/CTS mechanism [4] [7]. In BTMA, a base station broadcasts a signal to the other stations to eliminate the effect of hidden nodes when one station uses a channel. In Enhanced Busy Tone Multiple Access (EBTMA) [9], it uses two channels. The first one is used for transmitting the control packets

RTS/CTS/DATA/ACK, while the second one is used for transferring the busy tone signals.

A wireless network can handle the hidden node problem with the mechanisms that manages routing paths. The routing management with coordinator mechanism is proposed in [6]. This mechanism is used for grouping nodes into four phases. Coordinator is responsible for initializing the network formation, and also monitors all channels to determine collisions based on their event's time. The coordinator wants to collect the information of all nodes after detecting the collision. Based on this information, classify the nodes in different categories. The information gathering about the nodes is known as the polling phase. In this phase the coordinator starts transmission by an aware message. This message forces the nodes to enter the active mode so the coordinator sends the polling message for them in turn and waits for an ACK in response. This process is continued by each node. Thus all nodes have information about their hidden node. They send their information to the coordinator after receiving a report message from it. And the coordinator sends them to update the hidden node graph. Then the coordinator should start a grouping process based on the node's reports. In order to ensure that no hidden node exists in each group, nodes that are connected in the hidden node graph cannot stand in the same category. After grouping, the coordinators allocate a time interval to each group. And in each time interval, data can be transmitted. It is possible to manage the routing process by allocating the time interval. A coordinator should assign specific bandwidths to each group based on the group size.

The mechanisms that can be adopted in the networks which are heterogeneous due to their power differences, energy, range etc are as follows. In UAMAC [10] (Unidirectional-link Aware MAC), a node detects the presence of unidirectional links to its neighbours by utilizing some distance estimation scheme. The UAMAC assumes that there are specific frames carrying additional information to estimate a link status between a transmitter and a receiver. This information would be carried in periodic beacon frames or in RTS/CTS frames only exchanged when there are data packets to transmit. The beacon transmission mechanism [1] can be used for avoiding hidden terminal problem in heterogeneous network. The beacon transmission mechanism enables he receivers in a network to send beacon signals to prevent the hidden devices from accessing the channel. This mechanism does not require hidden node detection.

IV. Proposed System

The performance of heterogeneous wireless network may degrade due to hidden nodes in the network. The existing handshaking mechanism RTS-CTS cannot be adopted in the case of heterogeneous networks. Therefore, the objective is to overcome the hidden terminal problem in heterogeneous wireless networks.

The network can be heterogeneous in terms of their nodes physical parameters. The nodes in the proposed heterogeneous network shows heterogeneity in terms of their queue size, initial energy, transmission and reception power. The nodes in the heterogeneous network are attached to agents and the agent carries the application. The main responsibility of the agent is to create message packets.

The heterogeneous network includes sender nodes, intermediary nodes and receiver nodes. When any node (sender node) in the network scheduled for transmission it collects the neighboring nodes details. The neighboring nodes of the sender nodes send the neighboring nodes information to the sender nodes in the form of message packet. The message packet includes neighboring node ids.The message packet incorporates the details of the other nodes within the range of the access point. This will give prior information to every transmitting node about the existence of other nodes within the range of the access point. This neighbor node information can be used for the selection of routing. The existing routing protocol such as AODV protocol can be used for routing. The proposed method can be analyzed on the basis on throughput and packet drop The proposed system reduces the packet drops and thereby it achieves efficiency in throughput

A. System Architecture

The Figure. 2 illustrates the architecture of the proposed concept in heterogeneous network. The proposed message packet includes the details of neighboring nodes. This information can be used by the nodes for their further transmission.

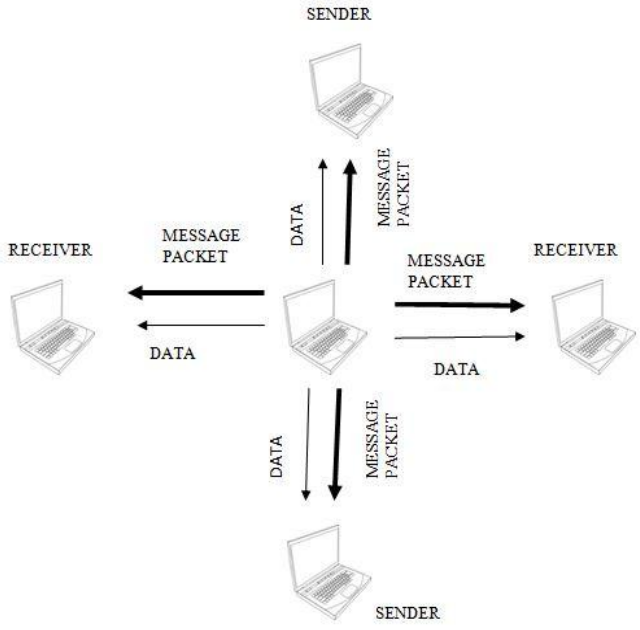

Figure. 2: Architecture of proposed System

In the proposed architecture, consider two nodes as sender nodes and receiver nodes. All nodes subsequently take part in communication. There is a chance of collision if both the sender nodes transmit the packet at same time. For avoiding collision sender nodes will collect the information about

neighboring nodes. The message packet received by the sender nodes includes the neighboring node's ids.

B. System Design

The system design deals with the designing of network model which represents a working model for the proposed concept. Proposed concept is simulated in network simulation tool. The message packet generation is also done in designing. The implementation of agents, application for packet is included in the message packet core files.

The designing of a network scenario results in a network model which consists of sender nodes, intermediary nodes and receiver nodes. The decisions on physical layer parameters for configuring the nodes are also done in designing. Here the nodes show heterogeneity in terms of their queue size, initial energy, transmission range, reception range. Node connectivity indicates TCP connections with nodes. Packet flows are take place in simulation scenario. Here source transmits packets to the sinks.

The routing protocols used for packet routing here is Ad-hoc on Demand distance vector (AODV). Efficient routing protocols can provide significant benefits to the networks in terms of both performance, reliability and initiates a route discovery process, which goes from one node to the other until it reaches to the destination or an intermediate node has a route to the destination. The proposed concept can be simulated using a 5 node scenario and it can be analyzed on the basis of packet drop and throughput.

V. Simulation Environment

The proposed method will overcome the hidden terminal problem in heterogeneous network. We implemented the proposed method in the Network Simulator- 2 (NS-2) and evaluated the two methods, beacon transmission mechanism and message packet transmission mechanism.

The proposed concept can be simulated by using a 5 node scenario. The nodes in the scenario transmits packet which includes details of neighbouring nodes ids for avoiding hidden terminal problem in heterogeneous networks. For the communication the nodes remain as fixed in scenario.

The nodes in the wireless networks show heterogeneous characteristics. The nodes can show heterogeneity in terms of their transmission and reception range, energy, queue size.

In order to avoid hidden terminal problem the packet format is modified. The packet format is modified by incorporating the details the details of neighbouring node. For a particular node identify the neighbouring nodes which are in the transmission of that node. And these neighbouring node ids are included in message packet for avoiding the hidden terminal. The details of the simulation are as follows.

A. Simulation Design

Table I shows simulation parameters. Then initialize global variables, simulator instance and trace file. Then setup topography object and god object. Then each node is configured with its parameters. Here the nodes shows heterogeneous characters Set the nodes position with its coordinate axis. Create a TCP agent and attach it to corresponding nodes and create FTP traffic sources and attach it to corresponding TCPs. And also create agent and traffic for message packet and attach it to corresponding nodes. Then schedule the events.

TABLE I
Simulation Parameters

Parameters	Environment
Channel type	Channel/WirelessChannel
Radio Propagation Model	Propagation/TwoRayGround
Network Interface Type	Phy/WirelessPhy
MAC type Mac/802.11	MAC
Interface Queue Type	Queue/DropTail/PriQueue
Link Layer Type	LL
Antenna Model	Antenna/OmniAntenna
Maximum Packet in interface Queue	50
Number of Wireless nodes	5
Energy	40.0
Routing Protocol	AODV
X Coordinate value	877
Y Coordinate value	489
Simulation Stop Time	50.0

The figure 3 shows a sample simulation scenario of proposed system. The proposed scenario includes 5 nodes, where node 3 and node 4 are the sender nodes and nodes 0 and 2 are receiver nodes. All nodes 0,1,2,3,4 subsequently take part in communication. There is a chance of collision at node 1 since both the transmitters i.e., node 3 and node 4 transmit the packet at same time. For avoiding this node 1 collects the information about neighbouring nodes and transmits it to node 4.

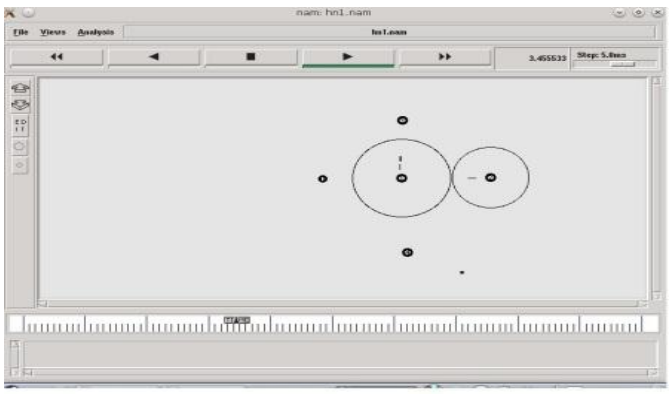

Figure. 3: Screen shot of proposed scenario.

VI. PERFORMANCE EVALUATION

The proposed system can be evaluated in terms of throughput and packet drop. Number of packets dropped is the number of data packets that are not successfully sent to the destination during the transmission. Throughput defines the rate of successful message delivery over a communication channel.

The proposal can be illustrated by three scenarios. The scenario 1 simulates the scenario with hidden nodes, scenario 2 simulates the beacon transmission by receivers and scenario 3 simulates the message packet transmission.

Table 1 shows the packet drop of these scenarios. Here the result shows that the message packet transmission is better than the beacon transmission method.

TABLE I
PACKET DROP ANALYSIS OF DIFFERENT SCENARIOS

Method	Packet Drop
Normal Scenario	56
Beacon Transmission	52
Message Packet Transmission	49

Table 2 shows the throughput of these methods. Here the message packet transmission method has high throughput than the other method.

TABLE II
THROUGHPUT ANALYSIS OF DIFFERENT SCENARIOS

Method	Average Packet Delivery
Normal Scenario	833.44 KB
Beacon Transmission	844 KB
Message Packet Transmission	856.4 KB

The simulation results will show the improvement in the throughput of proposed method and also the message packet transmission method reduces the packet loss.

The figure 4 shows the graphical representation of the throughput in proposed and existing concepts. The X-axis for the time and Y-axis for data received. The scenario for proposed system has high throughput when compared with existing ones.

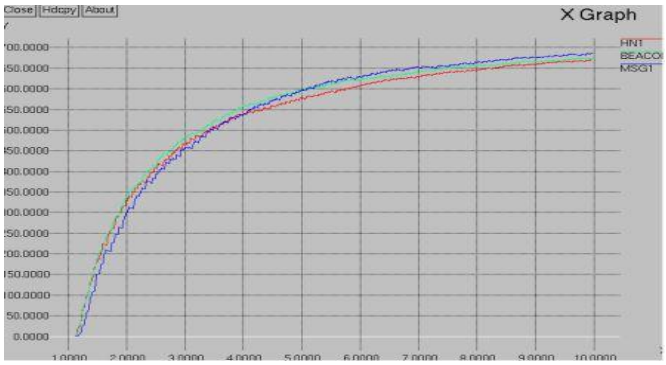

Figure. 4: Throughput

VII. CONCLUSION

Hidden nodes are a fundamental problem that can potentially affect any wireless network. Hidden nodes cannot receive any control packets. The packets are sent to the visible node regardless of any other nodes sending packets, which leads to problems such as collisions and packet loss. A hidden node problem is prevented by exchanging small RTS and CTS control frames in the homogeneous network. But the performance may degrade significantly, while used in the heterogeneous network environment. In order to overcome this problem a new packet is introduced to incorporate the details of the other nodes within the range of the access point in heterogeneous networks. The simulation results will show the improvement in throughput and it also reduces number of packet loss.

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