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MMRP: Multi Metric Based Routing Protocol for Streaming QoS Guaranteed Multimedia Data over 802.11n, 802.11b & 802.11g

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ABSTRACT: IIoT (Industrial Internet of Things) follows IEEE 802.11n specification that defines the standard for Medium Access Control(MAC) and Physical (PHY) layers which supports enhanced data transmission with reduced overhead and multiple spatial stream data transmission with different data rates. The downward compatibility of 802.11n specification with 802.11b and 802.11g allows co-existence of devices with different physical layer specifications i.e Different data rates across hops over a path in non-pure 802.11n based networks. Due to the downward compatibility of 802.11n and the support for multiple radios it allows the nodes with different physical layer specifications such as 802.11b and 802.11g to send and receive data. The variation in data rate introduces several challenges to ensure QoS (Data rate, Queuing delay, Transmission delay, Bit Error Rate and Jitter) guaranteed transmission of multimedia content. We analyse such a non-pure 802.11n network with different data rate and propose Multi Metric based Routing protocol for streaming QoS guaranteed multimedia over non pure 802.11n based network. Multi metric refers to transmission delay, buffer size and buffer service rate at each node. We propose a system model to represent the scenario and analyse the benefits through simulation in MATLAB. In contrast to COARP (Cache Optimized Adaptive routing Protocol) a well-known approach to predict path in pure 802.11n, we consider non pure 802.11n which consists of nodes with different physical layer specifications such as 802.11b and 802.11g. In addition we consider buffer servicing rate at each node. We evaluate the performance of the proposed algorithm in identifying and calculating path metrics such as data rate, queuing delay and jitter for supporting QoS guaranteed transmission in non-pure 802.11n network. We prove the efficiency of the proposed algorithm in finding a route that satisfies the QoS requirements of multimedia data in heterogeneous physical layer scenario and nodes with different queue servicing rate compared to the COARP that considers only pure 802.11n.

Keywords: Jitter, Multi Metric, QoS, Routing, 802.11n, Queuing delay, MMRP, MIMO.

Abbreviations: MIMO, Multi Input Multi Output; QoS, Quality of Service; IIoT, Industrial Internet of Things; MAC, Medium Access Control; ILP, Integer Linear Programming; DTN, Delay Tolerant Networks, MMRP, Multi Metric based Routing Protocol.

I. INTRODUCTION

The data rate supported by IEEE 802.11n PHY layer specification ranges from 6.5 Mbps to 600 Mbps depending upon the available number of spatial streams with each transmitting node. The MIMO (Multiple Input and Multiple Output) antenna option also supports variable data transmission rates across hops in a path between a source node and destination node. Recent works such as studied the diverse connectivity nature of 802.11n based IIoT networks (Industrial Internet of Things) [18]. The different type of connectivity includes well connected, partially connected and disrupted network conditions. Zhao *et al.*, [18] proposed a routing protocol which is adaptive to all kinds of network connectivity as stated above. The proposed approach considers link delivery delay, link disruption delay and buffer capacity available in each node while calculating a path from source to destination. We consider devices with different data transmission rate which can be supported using dual radio in the physical layer and also with different queue processing capacity. This heterogeneous characteristic of devices and communication channel in the network demands a customized routing mechanism particularly to transport multimedia data such as audio and video over non pure 802.11n networks. The Quality of service (QoS) requirements of multimedia data such as transmission delay, queueing delay, jitter, bit error rate and loss rate need to be considered while predicting the path from source to destination. In our proposed approach we consider heterogeneous types of network with different data transmission rate, queue servicing rate and jitter as a key metrics while predicting the path from source to destination with QoS support. Unlike COARP [18] and DSR [13], we consider non pure 802.11n which consists of nodes with different physical layer specifications such as 802.11b and 802.11g.

In addition we consider buffer servicing rate at each node. We prove the efficiency of the proposed algorithm in finding a route that satisfies the QoS requirements of multimedia data in heterogeneous physical layer scenario and nodes with different queue servicing rate compared to the COARP that considers only pure 802.11n. Moreover COARP [18] focusses more on handling diverse connectivity scenario where as the proposed work MMRP focuses on supporting QoS requirements of Multimedia data over non pure 802.11n. We provide a brief literature survey in section 2. Section 3 inspects the format of 802.11n MAC frame which is used in our analysis to calculate the queue servicing delay and transmission delay. The QoS requirement of multimedia data such as audio and video is provided in Section IV. Section V presents an analytical model for the proposed approach. Section VI presents the proposed algorithm. Section VII discusses on the results obtained through simulation in MATLAB. Section VIII concludes by identifying the future work of this paper.

II. RELATED WORKS

Xu *et al*., [1] provides an in-depth survey on the existing technological support for IoT in terms of devices, communication medium and protocol for integration. The authors in [1] provided the service oriented architecture (SoA) for IoT which includes layers such as sensing, networking, service and interface describing various requirements and operations of IoT devices. In addition, the authors discussed about technologies for device identification (RFID) and tracking the objects in IoT, networks (WSN and Adhoc), services and communications involved. The authors have provided the applications of IoT in healthcare industries, Food Supply chain, Mining applications with safety, smart transporting and fire detection and extinguishing mechanism

Tie *et al*., [3] designed a protocol that produces better good put and delay to a large extent in diverse network environment such as mesh and Delay tolerant Networks (DTN). The proposed routing protocol performs packet replication as a key operation to reduce delay and it is adapted dynamically by the routing protocol. The proposed protocol is tested through deployments, emulation and trace driven experiments on both Mesh testbed and DTN testbed and provides better performance in delay and goodput being, the first protocol tested on different testbed.

Latif *et al*., [5] proposed a new data dissemination scheme for VANET (Vehicular Adhoc Network) which is considered as an application of IIoT(Industrial Internet of Things). The vehicles in the VANET often encounter problems such as broadcast storm, disrupted network connectivity, disconnection between vehicles and limited bandwidth support. Existing data dissemination approaches works well in urban or highway scenarios. The authors proposed DDP4V (Data Dissemination Protocol for Vehicles in VANET) which effectively disseminate messages among vehicles by segmenting the transmission region of vehicles and selecting appropriate vehicles to forward messages to another vehicles. The proposed scheme improves network coverage, reduces overhead, collision and delay compared to the existing algorithms Asadpour *et al.,* [7] studied the issues that exist in data forwarding in MAV (Micro Aerial Vehicle) which disseminates aerially acquired images and videos to the ground. MAV encounters problem such as varying link quality and disrupted network connectivity among aerial vehicles due to obstruction caused by MAV frames. The authors proposed a scheme to forward packets based on the current position of MAV, its current speed and the possible location where the MAV will move in the near future.

Jain *et al.,* [11] proposed routing algorithms for delay tolerant networks. Delay Tolerant Networks (DTN) often causes unavailability of contemporary end-to-end paths. Moreover the delay between link failure and the restoration of link is high. The proposed work considers availability of constrained size buffer at each intermediate node to carry and deliver the message during link unavailability.

Johnson *et al*., [13] proposed DSR for multi-hop wireless adhoc networks which mainly has two operations named route discovery and route maintenance. DSR allows intermediate nodes to copy the route information from the ongoing traffic towards a particular destination. Updates on route are carried out only for the route which is used to currently carry the packets to a particular destination. The proposed algorithm is tested on open adhoc testbed.

Petersen and Carlsen [14] provided a systematic and technical view on the two most popular standards for wireless communications in Industrial automation named Wireless HART and ISA100.11a. Though the popular standards for wireless communication such as Bluetooth, ZigBee, IPV6 and 6LOWPAN exists, they are yet to achieve a breakthrough as a standard in Industrial automation. The authors presented a comprehensive review on these popular standards which can be useful while deploying application for Industrial Automations.

Clausen *et al*., [15] presents the description of OLSR which is an optimization of link state routing protocol (LSR). OLSR uses Multi Point Relays (MPR) to flood messages to other nodes in the network. Unlike LSR, number of messages flooded in the network is reduced significantly in OLSR.

Yang and Stoleru [17] proposed Hybrid Routing Protocol (HRP) that overcomes the issues faced in the existing algorithms such as predicting the place of replication, quantity of packets being replicated in wireless networks where inter-contact time between nodes is large. The proposed work considers delay and compute replication gain ingested into an algorithm to calculate route.

Draves *et al.,* [9] proposed a new routing metric based on the link bandwidth and loss rate for multi radio and multi hop wireless network. The work proposed a metric named WCETT (Weighted Cumulative Expected Transmission Time) to calculate path from the source to destination.

Krishnan and Arunkumar [20] discussed about adaptive routing for node efficiency in wireless sensor networks.

Dhamodaran *et al*., [21] discussed about efficient node ranking mechanism to thwart selective forwarding attacks.

Kumar *et al.*, [2, 4, 6, 16] proposed optimized algorithm to replicate data in multi hop wireless adhoc networks and HDFS clusters with reduced allocation time and QoS violated replicas. Kumar and Ilango [4] discusses the QoS requirements of multimedia data such as streaming videos. Delay, jitter, Loss rate, error rate and support for available bandwidth are considered as QoS need while transmitting video data.
Kumar *et al.*, [8, 10] presented the simulation studies to calculate the response time when a request is sent from a IoT device to a cloud server. The authors investigated with various link bandwidths.
Kumar *et al.*, [12] proposed a scheme to replicate data in VANET based on node density in city and sub urban area in order to reduce congestion in data forwarding.
Zhao *et al.*, [18] proposed unified metrics for routing protocols designed to operate in diverse network environments such as networks with well connectivity, networks with partial connectivity and networks with intermittent connectivity. Zhao *et al.*, [18] proposed ILP formulation using metrics such as delay and available buffer size in each node through which data is forwarded from source to destination. Delay includes conventional delay that occurs in link as well as delay due to link disruption between two nodes in the network. Based on the ILP formulation. Zhao *et al.*, [18] proposed a heuristic routing protocol named COARP (Cache Optimized Adaptive Routing Protocol) which performs well in diverse connectivity scenario compared to other popular routing algorithms such as DTN, PROPHET and DSR. Our work is similar to except that the routing metrics we identify support the QoS requirement of multimedia data while transferring a video from source to destination on 802.11n MAC [18]. The link weights are assigned based on the calculated support for QoS on each link and the route that supports the QoS need of multimedia data is selected as best route.

III. OVERVIEW OF 802.11N MAC FRAME

Compared to 802.11a, b and g, 802.11n supports data rate of 70 Mbps using OFDM, DSSS/CCK. The format of the 802.11n MAC Frame is shown in Table 1. It supports 150Mbps data rate using 40 MHZ bandwidth with multiple antennas.

Table 1: 802.11n MAC Frame Format.

Frame Control	Duration/ID	Add1	Add2	Add3	Sequence control	Add4	QoS Control	HT control	Frame Body	FCS
2 Octets	2 Octets	6	6	6	2	4	2	4	**0-7955**	**4**
← MAC HEADER →										

Generally devices are equipped with 2T3R (2 Transmitter and 3 Receiver) in multiple antenna configuration. 802.11n supports maximum of 4T4R. As an enhancement compared to the previous versions, 802.11n supports frame aggregation. There are two kinds of frame aggregation named A-MSDU and A-MPDU. In the former case, the aggregation is performed above MAC and below MAC in the latter case. Frame aggregation reduces the number of attempts made to access the channel as multiple packets are aggregated in a single large frame. At the other side aggregation may introduce noise as it stays for longer in the channel [19]. As shown in the MAC frame format in Table 1, QoS control and High throughput are newly added in the recent standards of 802.11n. With the maximum number of transmitters and receivers (4T4R) it is possible to achieve 550 Mbps of transmission rate in 802.11n.

IV. QoS PARAMETERS FOR MULTIMEDIA

Response time: The elapsed time between the submission of request from client and the arrival of response from the server. The response time depends on the context such as client and server connected with high bandwidth connectivity and higher processing capacity of server. The response time also varies based upon the congestion level in network at a particular point of time.
Delay: The amount of delay is defined such that the elapsed time between placing the first bit of data at source and the reception of same in the receiver side. As per the recommendations in ITU G.114, 150ms is an acceptable level of delay to hear audio in a perceptible manner [13]. While streaming video, the packets that contains video and audio are transmitted separately. Lip synch is a notable parameter in video streaming which should be less than 100 ms leading to a requirement of 250 ms delay of streaming video.
Jitter: The observed variation in delay over a channel is called as a jitter. Applications like real time sound are sensitive to jitter. Delay compensation and equalization are the key techniques to handle jitter in real time sound. The value of jitter should be between 20-30 ms for applications such as virtual reality.
Bandwidth: Bandwidth determines the speed at which the data will get transferred from one point of network to the other. Larger the bandwidth, better will be the support to transfer data specifically of multimedia type that contains audio and video transmitted simultaneously. As per 802.11n, bandwidth at a rate of 54 Mbps, 70 Mbps and a maximum of 550 Mbps are available across the network to carry data from one device to the other.
Loss rate: It measures the number of bits lost during transmission between any two points in the network. Loss rate is comparatively high in wireless medium than wired due to channel interference and obstacles on the path between sender and receiver. Moreover the support for bandwidth is also less in wired medium. For transmission of video and audio, the loss rate should be within an acceptable range.

Table 2: QoS metrics for Multimedia on web [19].

Traffic Class	Delay(ms)	Jitter (ms)	Lip-Synch	Required Bandwidth (bps)	Response to Interactive function
Interactive Video On Demand	<150		<100ms	1.5Mbps	Response to Interacive function 2-5 sec
VCR Quality (MPEG-1)		<100		1.2 to 1.5 Mbps	
Video quality		<50		4-60 Mbps	
HDTV (MPEG-2)		<50			
Multimedia on Web (MPEG-4)		<150		28.8-500 Kbps	

Table 3: Bandwidth and Delay constraints for Video Transmission [19].

Multimedia Applications	Bandwidth	Delay
HD Telepresence	24Mbps	50ms
Telemedicine and remote surgery	10Mbps	1ms
Video Instant Messaging and Video Presence	10Mbps	4ms
HD TV	8Mbps	
Real Time Data Back Up	2Mbps	10ms

Error rate: The number of bits modified during the transmission of a packet from one point to the other in the network. As shown in Table 2 and 3, we provide the expected QoS attributes for transmission of Audio and Video [19].

V. SYSTEM MODEL

As shown in Fig. 1, nodes which are part of a IIoT (Industrial Internet of Things) have multiple paths between a particular source and destination. A path consists of multiple hops with various transmission capacity. The transmission capacity is determined by the data rate supported by the PHY layer across each hop. In pure 802.11n network the data rate supported across all hop is same. As 802.11n supports legacy IEEE 802.11b and 802.11g where the PHY layer definition of later supports different data rate (possibly lower than 802.11n), hence it is possible to have heterogeneous data rates across hops from the source to destination in non-pure 802.11n networks. In contrast to the proposed work in [18], we consider different PHY layer channels that supports different transmission rate in our analysis to find a path between source and destination. The path determined by our proposed work

ensures shorter transmission delay from source to destination, shorter queuing delay on each intermediate node and less jitter across the multi hop path to ensure QoS guaranteed transmission of multimedia data such as video and voice. The expected support for QoS while transmitting the multimedia content is listed in Table 2 and 3.

We define the following metrics used in our analysis.

NC_NW: Represents the number of nodes available in the network**.**

TR_HOP: Data transmission rate supported over a hop. 802.11n supports various data rates based on the number of antennas available in the transceiver of a node. It also uses various modulation schemes such as BPSK, QPSK and 64-QAM with various coding rates. Using channel bonding technique the data rate is doubled in 802.11n.

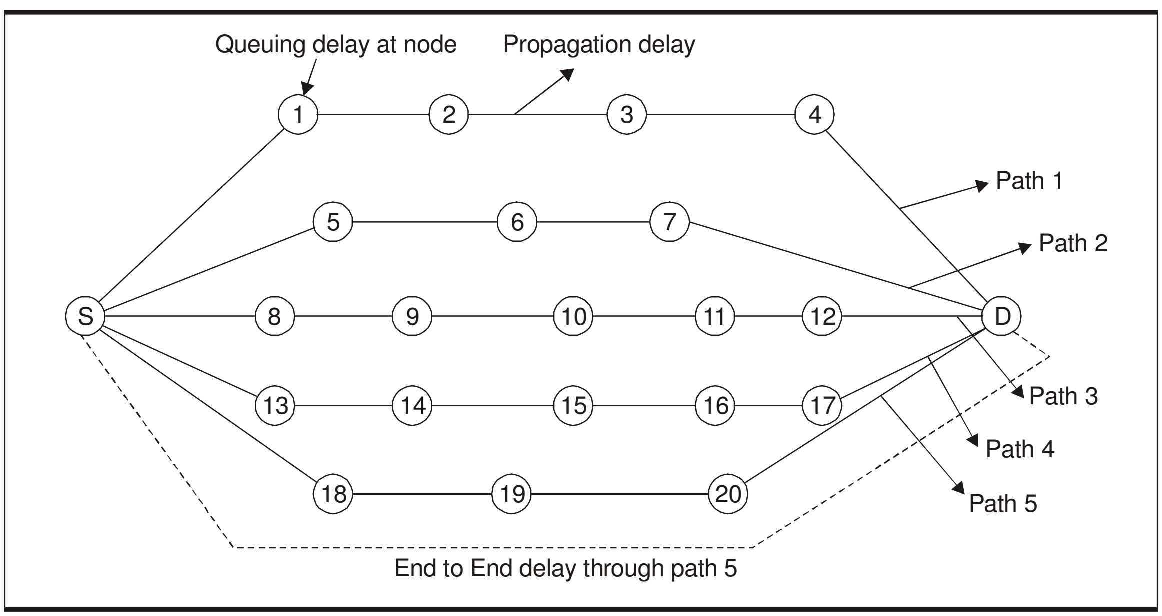

Fig. 1. Availability of multiple paths in 802.11n, 802.11b and 802.11g based IIoT.

The single spatial stream supports data rate between 6.5 Mbps to a maximum of 150 Mbps using coding rate 5/6 and guard interval 400ns. A maximum of 600 Mbps is theoretically achievable using 4 spatial streams and 64-QAM modulation technique with 400ns guard interval in 40 Mhz channel. Fig. 2 shows the variation in data rate across various hops.

TD_HOP: Transmission delay over a hop in a path from source to destination.

$$TD\_HOP = \frac{\text{RTT (For a Probing Packet)}}{2} \quad (1)$$

OD_PATH: Represents the overall delay. Total delay is the sum of delay over all hops along a particular path. The delay depends upon the number of hops in between the source and destination and the data rate supported by each hop.

$$OD\_PATH = \sum_{i=1}^{NH\_PATH} D\_HOP(i) \quad (2)$$

QD_PATH: Summation of queuing delay in nodes across a path from a source to destination

$$QD\_PATH = \sum_{i=1}^{n} QD\_NODE(i) \quad (3)$$

where n is the number of intermediate node between a source and destination

NH_PATH: Number of hops over a path between source and destination. As shown in Fig. 1, multiple paths can exist between a source and destination with various hop counts. A routing algorithm always selects a path with shorter hop count and also which satisfies a set of criteria such as delay, jitter and bandwidth. There are five paths available from source to destination in the scenario given Fig. 1. Path 1 consists of four hops and path 2 with three hops and so on.

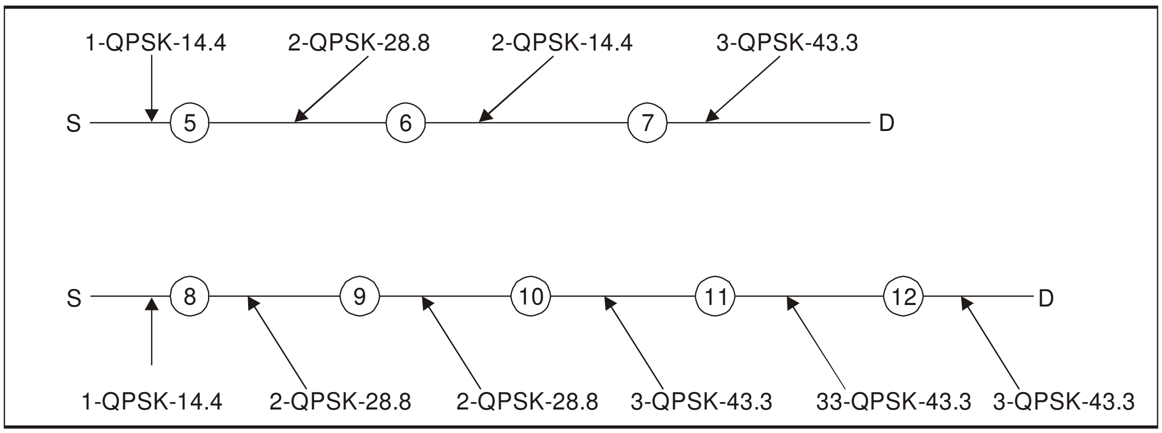

Fig. 2. Variations in channel capacity and transmission delay.

PACKET_SIZE: Size of a data packet in bytes that will be transmitted across a multi hop path between a source and destination. The size of a packet plays a crucial role in determining the delay and throughput. The size can vary from 128, 256, 512, 1024 and 2048 bytes.

QS_NODE: Queue size of a node in packets. It determines the capacity of a queue available in each intermediate node to hold data packets when the arrival rate is larger than the processing capacity of an intermediate node. The packet drop can be minimized by keeping the size of the queue as larger as possible.

QD_NODE: Queuing delay a data packet encounters on each node. This specifies the amount of time a packet spends in the queue of each intermediate node when transmitted from a source to destination. Fig. 3 shows the variation in queuing delay in each node across a path.

$$QD\_NODE = \frac{\text{No. of packets in the queue}}{\text{Queue service rate}} \quad (4)$$

where Queue service rate is defined by the number of packets serviced per time unit.

EED_PATH: The total delay experienced by a packet from source to destination. EED_PATH varies for different path that exist between a source and destination and it is determined by the queuing delay and transmission delay across several hops from source to destination. The transmission delay is mainly depends on the data rate supported over a hop along the path.

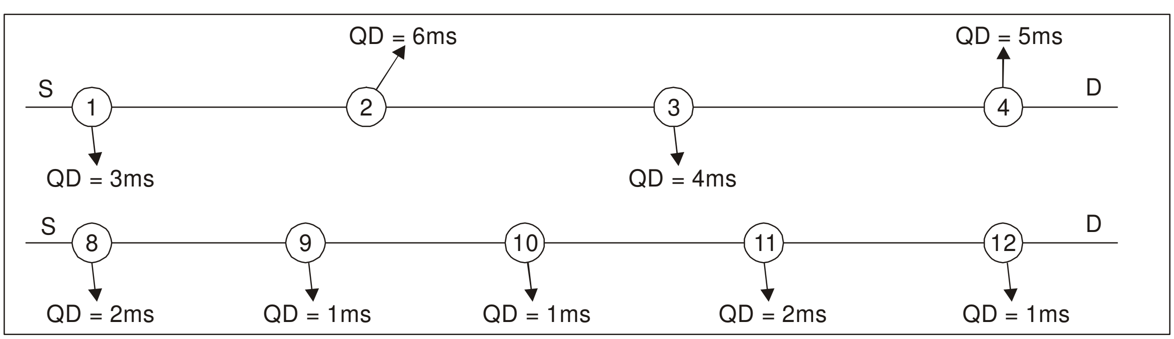

Fig. 3. Queueing delay in each node over a path from source to destination.

EED_PATH= $OD\_\text{PATH} + QD_{\text{PATH}}$ (5)

PATH_JITTER: The observed variations in delay over a particular path. Jitter can be measured by averaging the delay observed over a sequence of transmissions in a path. Fig. 4 shows availability of path between source and destination with different jitter values.

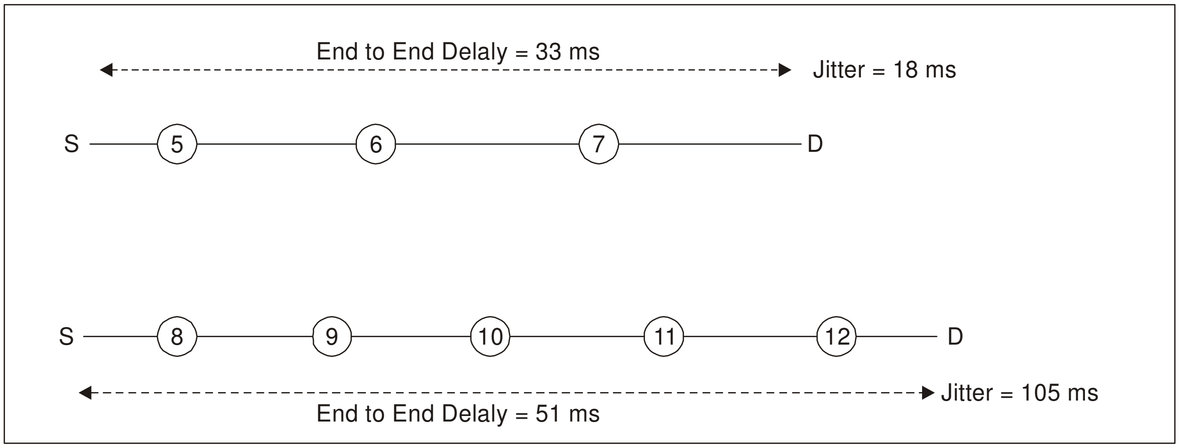

Fig. 4. Illustration of Jitter along paths available between source and destination.

PATH_JITTER=($\sum_{i=1}^{n}$ Difference in consequtive Delay) / (n-1) (6)

where n-1 is the number of samples of delay for which the difference has been calculated. Jitter is an important metric to support QoS of multimedia data over a network. The existing protocol such as COARP [18] considers the link delivery delay, link disruption delay and buffer size while predicting path from a source to destination. It works well for networks with well connectivity, partial connectivity and disrupted networks. But the need to ensure QoS while transmitting the multimedia contents is not being addressed. Moreover the work in [18] considers pure 802.11n network where the data rate for all hops are same. But in our proposed work, we consider the existence of heterogeneous communication channel between nodes. These heterogeneous characteristics of network might throw additional challenges such as jitter, bit error rate and loss rate. We consider the additional QoSmetrics such as queuing delay and jitter while predicting route from a source to destination to ensure QoS while transmitting multimedia content.

NN_INFO: Every node determine its set of neighbours and maintains information about them such as delay and jitter over the channel to reach them .

DELAY_QoS: Minimal delay requirement to transport multimedia content

JITTER_QoS: Minimal Jitter Requirement to transport multimedia content

VI. MULTI METRIC BASED ROUTING PROTOCOL FOR STREAMING QOS GUARANTEED MULTIMEDIA OVER 802.11N, 802.11B & 802.11G

Inputs:

NC_NW: [10, 20, 40, 60, 80, 100]

TR_HOP: [1-QPSK-14.4Mbps, 2-QPSK-28.8Mbps, 1-QPSK-14.4Mbps, 3-QPSK-43.3Mbps]

QS_NODE: [2k, 4k, 8k , 16k, 32k]

PACKET_SIZE(in Bytes):[256, 512, 1024, 2048, 4096]

Detect_Neighbours()

{

For all nodes in NC_NW

Each Node transmits a probe packet to its neighbor;

Wait for Response from the neighbor;

After receiving the response from neighbor

Calculate the RTT;

Calculate Delay to reach each neighbor and assign it to TD_HOP;

Estimate the channel capacity and assign it to TR_HOP;

Update NN_INFO;

}

Update Neighbour_Info()

{

Each node transmits the neighbour Information to other nodes in connectivity;

After receiving neighbour Info from a node, each node updates its informationbased on the information received such as neighbour node and hop count, queue size, supported data rate over a hop.

}

Find_Route_QoS_Support(S,D)

{

*Node **S** based on the updated Neighbour Info initiates Route Detection to Node **D**;*

*Node **S** finds all possible paths to **D** with various hop distance*

For each path from S to D

{

Calculate NH_PATH.

For each hop in NH_PATH

Find TR_HOP

Based on TR_HOP for a given channel

For a given packet size from [256, 512, 1024, 2048, 4096]

Calculate TD_HOP;

Calculate OD_PATH;

}

For each path from S to D

{

For Each node along the path from S to D

Find the queue size in each node QS_NODE

For a given packet size from [256, 512, 1024, 2048, 4096]

Calculate QD_NODE

Calculate QD_PATH

}

For each path from S to D

{

Calculate EED_PATH and PATH_JITTER such as

EED_PATH= OD_PATH + QD_PATH

PATH_JITTER=
($\sum_{i=1}^{n} Difference\ in\ consequtive\ \ Delay$) / (n-1)

Select from available paths such that

(EED_PATH <DELAY_QoS&& PATH_JITTER <JITTER_QoS)

Return path;

}

}

VII. ANALYSIS

We consider 802.11n networks which is a standard for IIoT (Industrial Internet of Things). The PHY layer standards defined for 802.11n is downward compatible with other specifications such as 802.11b and 802.11g. A pure 802.11n network consists of devices only with similar data transmission support. In other cases, a non-pure network can be formed using devices that follows different 802.11 PHY layer specifications such as 802.11n, 802.11b and 802.11g. In this case the data rate supported on each hop over a path between a pair of source and destination varies. The difference in the transmission capacity can be handled using dual radio on each network interface available. This introduces higher delay during data transmission particularly when the communicating nodes are farther. Due to the variations in the channel capacity, data transmissions may suffer from a problem called jitter, which is essential to support QoS for multimedia content. In addition to the link delivery delay as in [18], we also consider delay introduced in each node while processing the data in the queue. As queuing delay varies for different devices which are part of a network , we consider the queing delay in addition to transmission delay as in [18]. The end to end delay is calculated as sum of transmission delay and queuing delay over a path between a pair of source and destination. We analyse the proposed routing mechanism under well connected networks. During partial connectivity and disrupted connectivity the routing mechanism can be followed as discussed in [18]. The packet size is varied from 256 to 4096 to analyse the benefits of the proposed routing mechanism. We compare the proposed Unified Multi Metric based Routing protocol with COARP [18] in a well-connected network condition only. We consider the queuing delay in each intermediate node against the size of buffer in COARP. As we are focused to support QoS for multimedia content, we analyse the performance of the protocol to support the QoS guaranteed transmission.

Table 4: Simulation configuration for Homogeneous Bandwidth and Queue Servicing rate (25 packets per second).

No. of hops in path varied from 3, 5, 7, & 9
Data rate on each hop: 14.4 Mbps
Size of data to be transmitted from source to destination =1MB (1048576 bytes)
Packet Size (MAC Header & Footer +Payload) =2346 Bytes
Transmission time per packet over a hop =0.0013 seconds
Queue servicing rate = 25 packets per second

As shown in Table 4, we configure the simulation parameters such as the number of available paths from source to destination and number of hops in each path. We vary the number of hops from 3, 5, 7 and 9 between source and destination. We set the data rate on each hop as homogeneous with 14.4 mbps. The size multimedia data that will be transmitted is set to 1 MB and the size of each packet is set to 2346 which is the sum of MAC 802.11b/g header and payload. The queue servicing rate is set to 25 packets per second. It is varied from 5 to 25 packets per second as shown in the Table 6.

Table 5: End to End delay in paths with different hop-count with homogeneous bandwidth (14.4 Mbps) and queue servicing rate (25 packets per second).

Path	No. of hops	Total Queuing Delay (in seconds)	Total Transmission delay (in seconds)	End to end Delay (in seconds)
Path-1	3	0.02320	1.7433	1.7665
Path-2	5	0.03866	2.9055	2.9441
Path-3	7	0.05413	4.0677	4.1218
Path-4	9	0.06960	5.2299	5.2995

Table 6: Simulation configuration for Homogeneous Bandwidth (14.4 Mbps) and Queue Servicing rate (5 packets per second).

No. of paths from source to destination: 4
No. of hops in path varied from 3, 5, 7 & 9
Bandwidth on each hop: 14.4 Mbps
Size of data to be transmitted from source to destination =1MB (1048576 bytes)
Packet Size (MAC Header & Footer +Payload) =2346 Bytes
Transmission time per packet over a hop =0.0013 seconds
Queue servicing rate = 5 packets per second

As shown in Table 5, the queuing delay in each path varies from 0.02320 seconds to 0.06960 seconds. The QoS specifications for multimedia data such as audio and video demands a minimum delay of 150 ms. The nodes in the network can transfer data with minimal queuing delay when the queue service rate is higher. The minimum queuing delay in this case is 23.2 milli seconds in a path with three hops and the maximum queuing delay is 69.6 milli seconds in a path with 9 hops.

Table 6 shows the simulation configuration where the queue servicing rate is set to 5 packets per second. As it can be observed from Table 7, queuing delay increases due to the decrease in the queue servicing rate. The minimum delay in this case is 116 milli seconds and the maximum delay is 348.1 milliseconds. For transporting multimedia data the QoS requirement for delay is within 150ms. In this case the QoS can't be guaranteed as there exist no path that can support the required delay.

Table 8 and 9 shows the simulation parameters and the results obtained when the data rate across the hops in a path are set to different rates such as 14.4 Mbps, 28.8 Mbps and 43.3 Mbps. The queue servicing rate is also varied from 5 to 25 packets per second. The minimal queuing delay in this case is 57.9 milli seconds and the maximum delay is 116 milliseconds. Though the number of hops in path-4 is more, the queuing delay is less compared to a path with three hops such as in path-1.

Table 7: End to End delay in paths with different hop-count with homogeneous bandwidth (14.4 Mbps) and queue servicing rate (5 packets per second).

Path	No. of hops	Total Queuing Delay (in seconds)	Total Transmission delay (in seconds)	End to end Delay (in seconds)
Path-1	3	0.1160	1.7433	1.8593
Path-2	5	0.1933	2.9055	3.0988
Path-3	7	0.2706	4.0677	4.3383
Path-4	9	0.3481	5.2299	5.5779

Table 8: Simulation configuration for Heterogeneous Bandwidth and Queue Servicing rate.

No. of paths from source to destination: 4
No. of hops in path varied from 3, 5, 7 & 9
Bandwidth on each hop varied from: 14.4 Mbps, 28.8 Mbps and 43.3 Mbps
Size of data to be transmitted from source to destination = 1MB (1048576 bytes)
Packet Size (MAC Header & Footer + Payload) = 2346 Bytes
Transmission time per packet over a hop =0.0013 seconds, 0.000621seconds and 0.000413 seconds
Queue servicing rate = 5, 25 & 50 packets per second

Table 9: End to End delay in paths with different hop-count with Heterogeneous Bandwidth and Queue Servicing rate.

Path	No. of hops	Total Queuing Delay (in seconds)	Total Transmission delay (in seconds)	End to end Delay (in seconds)
Path-1	3	0.1160	0.6468	0.6584
Path-2	5	0.1276	2.2984	2.4260
Path-3	7	0.1353	2.7606	2.8960
Path-4	9	0.0579	3.4334	3.4914

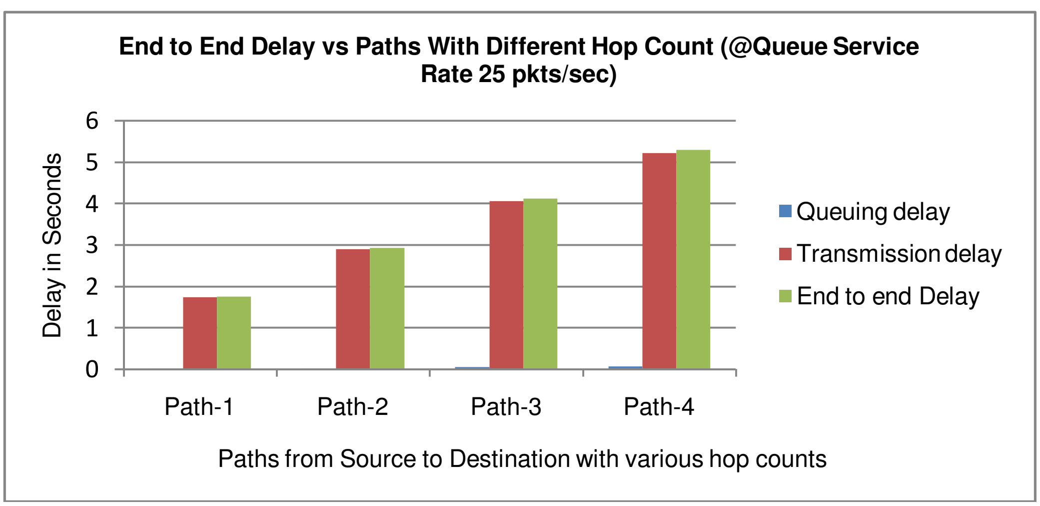

Fig. 5. Delay vs path with various hop count with equal bandwidth (14.4 Mbps) and queue servicing rate (25 Packets per second).

Fig. 5 through 7 presents the comparison of total delay (in seconds) versus paths with different number of hop count. Fig. 5 compares the results obtained with 25 packets per second as a queue servicing rate. Fig. 6 compares delay in each path when the queue servicing rate is set to 5 packets per second. Fig. 7 presents the delay in each path when the queue servicing rate and the data rates are varied across each hop.

As it can be observed from the simulation results, the delay across each path varies according to the data rate supported across each hop and the queue servicing rate at each node. Our proposed approach MMRP (Multi Metric Based Routing Protocol) considers the queuing delay across each hop within a path in addition to the link delivery delay as in COARP [18].

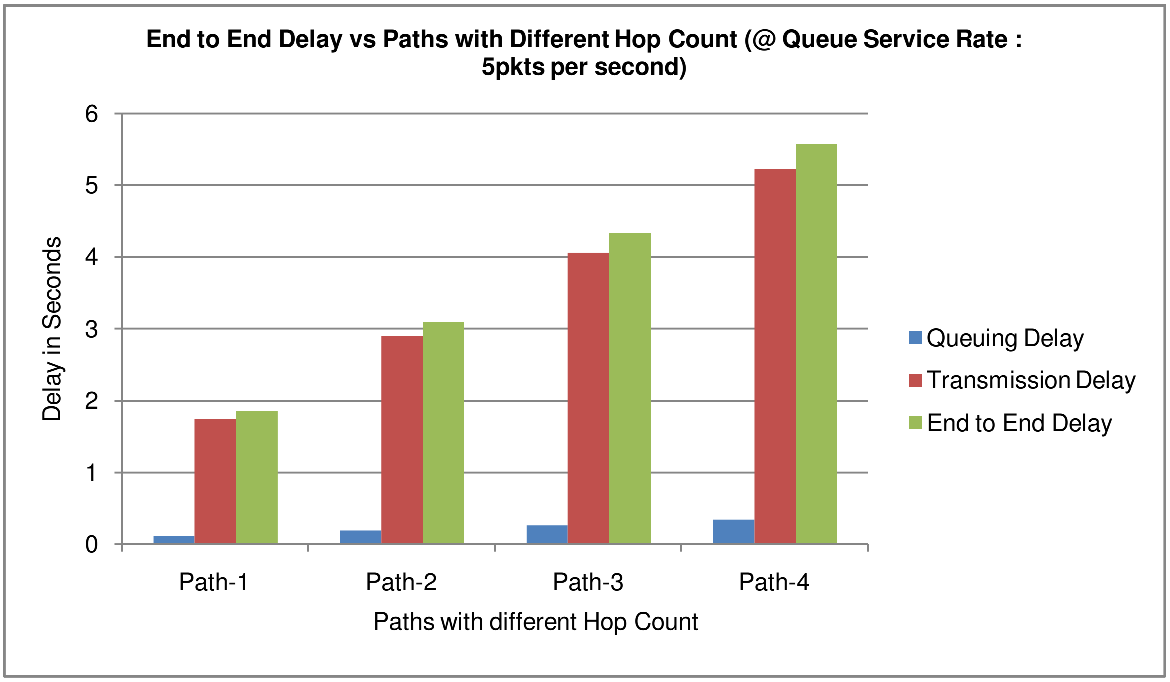

Fig. 6. Delay vs path with various hop count with equal bandwidth (14.4 Mbps) and queue servicing rate (5 Packets per second).

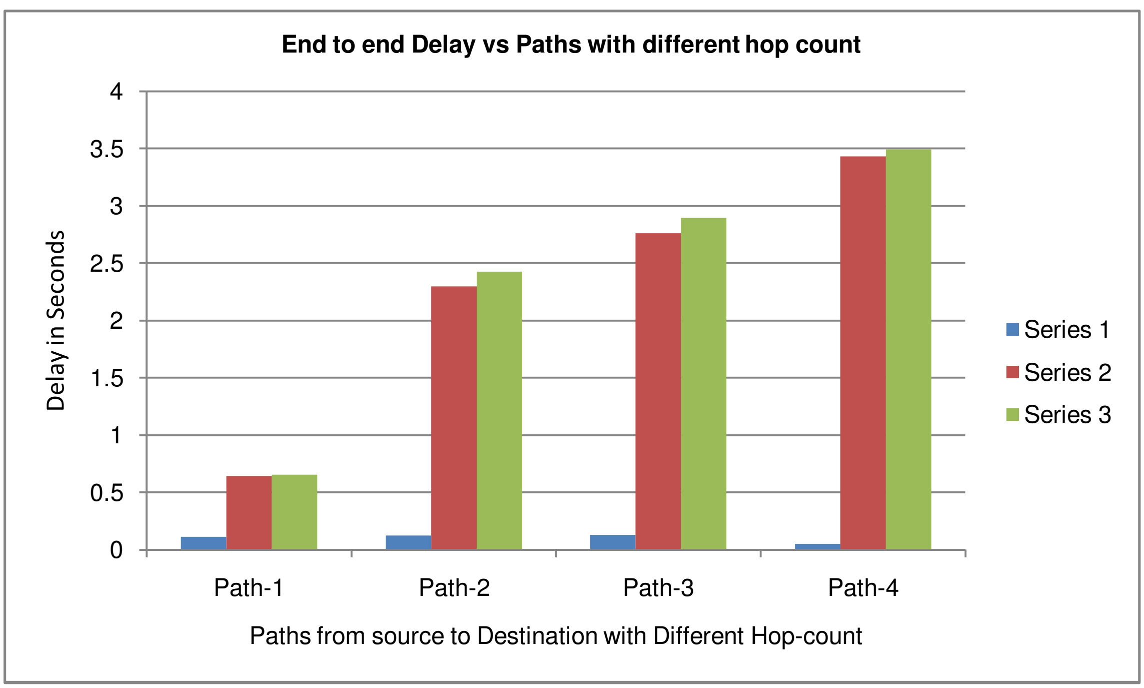

Fig. 7. End to End delay in paths with different hop-count with Heterogeneous Bandwidth and Queue Servicing rate.

In addition to queuing delay we also consider jitter across each path which can be measured as an average of delay of several transmissions over a path. These two additional metrics (Queuing delay and jitter) helps to ensure QoS guaranteed transmission of multimedia data such as audio and video with minimal delay and jitter. The calculated path metrics are taken as input and the algorithm selects a path with minimal queuing delay, jitter and end-to-end delay among the available paths.

VIII. CONCLUSION

The work in this paper analyses the heterogeneous characteristics of networks based on 802.11n, 802.11b and 802.11g in terms of difference in data rate supported across each hop and queue servicing rate of each node across a path. In contrast to the recent approaches such as DSR and COARP which considers pure 802.11n and finds optimized route to a particular destination, the proposed approach Multi Metric Routing Protocol (MMRP) considers non pure 802.11n based network that consist of nodes with various physical layer specifications such as 802.11b and 802.11 g. This can be achieved due to the fact that 802.11n is downward compatible with its earlier standards and moreover it supports dual radio. As the network consists of nodes with heterogeneous physical layer specifications and varying queue servicing rate, it throws a challenge to guarantee the QoS requirement of transmitting multimedia data over it. We propose MMRP that finds a route to support QoS need of multimedia data transmission such as bandwidth, queuing delay, transmission delay and jitter. The work proposes a multi metric based routing algorithm to support QoS guaranteed transmission of multimedia data over non pure 802.11n networks. Terminologies and system model to represent the proposed approach is presented and simulated in MATLAB. The efficiency of the proposed algorithm is tested with different hop count, queue servicing rate and different transmission rate. The proposed multi metric based routing protocol calculates the path metrics such as queuing delay, transmission delay and jitter to find a path to support QoS while transmitting multimedia data in non-pure 802.11n networks compared to the existing works such as DSR and COARP which works on pure 80211n. As part of the future work, we plan to investigate the performance of the proposed approach in a real network scenario.

Conflict of Interest. There is no conflict of interest.

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