International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 8 (2017) pp. 1564-1575

Enhancing Transport of Media Using Physical Layer Based Approach

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Abstract

Wireless networks became ubiquitous. Moreover, due to technology innovations, wireless networks are able to accommodate multimedia streaming applications. As a result wireless networks moved from simple data transfer to loss-tolerant, delay-sensitive and bandwidth-intensive multimedia applications. As people of all walks of life started using smart phones and the wireless networks encompass them as well, it is inevitable to address issues pertaining to quality of service (QoS). The Open Systems Interconnection (OSI) model has plethora of adaptation strategies and protection methods that exist in different layers. When it comes to multimedia applications there are many aspects such as spectrum utilization, power consumption, multimedia quality and implementation complexity to be considered. These aspects are provisioned in different layers of OSI. Therefore it is essential to comprehend the layers and their functionalities with respect to these aspects and tradeoffs between them. Thus it is understood that there is cross-layered approach to make the multimedia applications to relay on wireless networks successfully. In this paper we proposed a cross layered design approach. However, we implemented physical layer improvements and studied the dynamics of transport of media in wireless networks. Complete implementation of the proposed CLD is deferred to future work. The proposed solution will have comparable performance and effectiveness with existing ones. A simulation study is made and results are analyzed for proof of concept.

Keywords: Cross layer design, physical layer, transport of media, wireless networks

INTRODUCTION

It is well known fact that improvements in telecommunications in terms of 3G and 4G led to mobile multimedia network systems. As mobiles are used by people of all walks of life, it became imperative for research community to focus on multimedia transmission over wireless networks. As wireless devices have mobility and convenience, they are widely used in the real world. Such devices are capable and connected to electronic super high way, the Internet. Mobile devices are involved in transmitting digital multimedia. There are many motivating scenarios where wireless devices need to participate in multimedia communications. One such scenario is m-health or mobile health which is the practice of public health and medicine where mobile devices are involved. In this paper we considered m-health scenario as a motivating example which shows the need for high quality video streaming over wireless devices.

The recent innovations in 4G broadband networks resulted in many multimedia applications that render services through wireless networks. However, there are many issues encountered in the process of multimedia transmission over such networks. The issues include channel fading, deterioration of video quality, sudden fluctuations in the network, jumping and so on. Therefore it is to be understood that in applications pertaining to m-health, video quality is important. Therefore, it is essential to have application level QoS requirements, so that the whole thing can be optimized. Many researchers contributed towards optimization of multimedia transmission over wireless networks. However, the research in the area of cross layer design for optimization is still an open problem to be addressed.

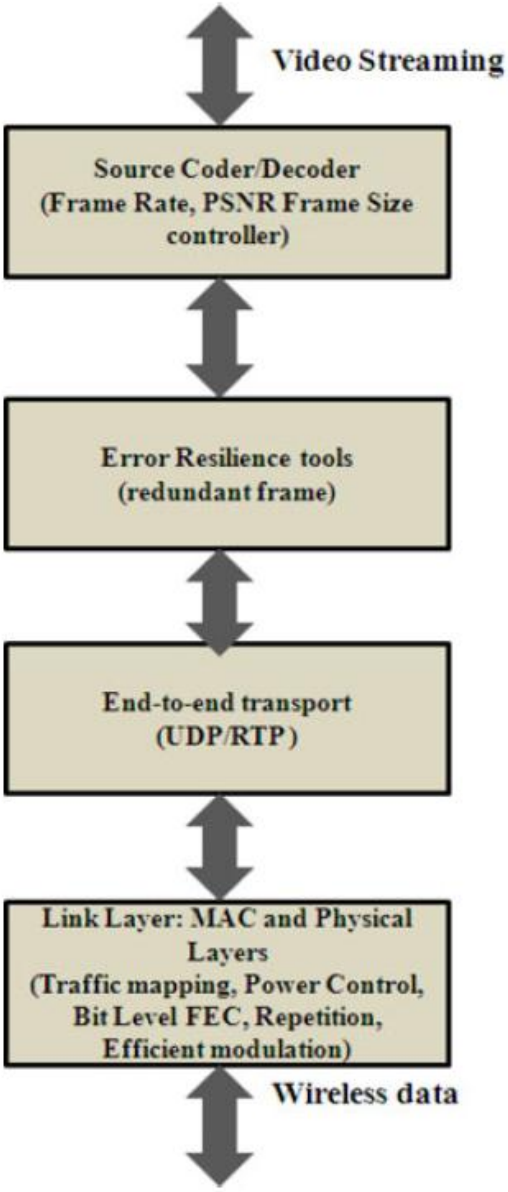

Figure 1 – General video streaming phenomenon over wireless networks [17]

As shown in Figure 1, the video streaming over wireless networks involves the lower layer named link layer which needs MAC and physical layers for improving video streaming as per the QoS requirements of multimedia application. Our contributions in this paper include the cross layer design with joint optimization of MAC and PHY layers. However, the implementation is confined to the PHY layer only. MAC layer optimization and joint optimization are deferred to our future work.

The remainder of the paper is structured as follows. Section II provides review of literature. Section III presents a motivating scenario pertaining to m-health domain. Section IV provides problem definition and methodology. Section V presents the implementation of PHY layer optimization. Section VI presents simulation results while section VII concludes the paper.

RELATED WORKS

This section reviews literature that is related to optimization of multimedia communications over mobile networks. Khan et al. [1] used physical and data link layers for optimization purposes. With respect to physical layer two parameters are considers. They are transmission rate and packet error probability. This is considered for all users and different modus operandi. They compared physical layer parameters like throughput with cross layer approach. They found that user perceived quality is improved when they used cross layer approach. The parameters used for quality improvement are mapped directly to user perceived quality in order to estimate the effectiveness of the approach.

Bouras et al. [2] focused on multimedia transmissions over wireless networks. Their research revealed that fact that optimization of one layer in can affect other layers too. However, there are two possibilities. First one is optimization can be made in one layer without affecting other layers. Second one is that optimizations are done in one layer affect one or more layers. They opined that cross layer adaptation can be made with different layers for different parameters. For instance, signal modulation in physical layer; ARQ, FEC, QoS in MAC layer; adaptive transmission rates in transport session; encoding parameters in application layer.

Wu et al. [3] explored physical layer optimization along with other layers such as application and data link layers. Adaptive modulation and coding (AMC) was used at the physical layer for enhancing video transmission quality. They opined that AMC was studied in the literature extensively for ensuring that content transmission is compatible with time-varying channel conditions. In such conditions packet loss can be avoided by using AMC. In order to achieve high reliability at physical layer two things are possible. They are reducing data transmission rate and powerful error-correcting codes. Another means of reducing packet loss is to use Automatic Repeat Request (ARQ) in the link layer in order to get the packets subjected to error to be retransmitted again.

Shan [4] focused on explored many techniques for cross-layer approaches in order to improve video streaming in wireless networks. Both channel and data are considered for adaptive video streaming. A packetization scheme is used for constructing an application layer packet and then decomposes into many Radio Link Protocol (RLP) packets. RLP layer granularity and application layer adaptivity.

Stine et al. [5] opined that mapping wireless networks to wired nodes and links can help in achieving Quality of

Service (QoS). In this context electro-magnetic spectrum is a critical resource. They focused on node states and synchronous signalling for improving QoS in wireless ad hoc networks. Dissemination of node states concept is used to resolve topology issues. An intuitive framework is provided in order to exploit RF media and techniques pertaining to traffic engineering.

Chiang [6] focused on physical and transport layers for optimal power control and congestion control. They projected layering concept as optimization decomposition. The overall problem is considered as network utility maximization problem. The improvement at each layer is considered as decomposed sub problem. The interfaces found in all layers are considered as variables quantified for optimization. Moreover they presented an algorithm named distributed power control algorithm that works in tandem with congestion control algorithms of TCP for energy efficiency and increased end-to-end throughput in wireless multihop networks. There was optimal balancing between supply and data rate demand. Their algorithm was found robust to path loss estimation errors and wireless channel variations.

Wu et al. [7] studied physical-layer broadcast and network coding for information exchange in wireless networks. Physical layer broadcast and network coding can help in achieving same transfer rate while reducing usage of channel power and other resources besides facilitating mutual exchange. By using a phenomenon known as physical piggybacking their distributed scheme achieved advantages when compared with conventional routing.

Shah and Islam [8] provided an overview of cooperative communication in wireless networks for mitigating channel impairments that may occur due to multipath propagation. Spatial diversity of channels is exploited by using cooperative communication. In co-operative communication each user acts as both as a user who receives information and relay to send data to other node in cooperative fashion. This will improve communication in such networks. In code rates and transmit power interesting trade-offs are observed when cooperative communication is explored.

Ahlswede et al. [9] focused on the problem of network information flow. This problem is associated with computer network applications. They used an information flow and worked out characterization of coding rate region. They named their work as max-flow min-cut. They found that by using network coding at nodes bandwidth consumption is reduced. Li et al. [10] focused on a scenario where source nodes involve in multicasting and other nodes are also involved in passing information to other nodes. In the process they improved information flow using linear network coding. Network coding is the process of working with bits of information by performing logical operations in order to reduce the overhead in communication. Koetter et al. [11] performed network coding using algebraic approach. They found that network coding improved the capacity of network. Wu et al. [12] focused on layered model in wireless networks for efficient communication. In the physical layer model, minimum energy-per-bit is achieved by using network coding. Besides it helped in finding optimal solution with respect to polynomial time. They modelled network as graph made up of trees that reflect the physical broadcast links. Total cost is reduced by employing minimum-energy multicasting.

Lun et al. [13] employed cost as criterion while performing network coding. They focused on achieving minimum-cost routing by employing network coding. They found that it is possible to have minimum-cost routing and optimize communications using network coding. They considered their research in wireless networks as linear optimization problem. Wu et al. [14] considered network planning problem. They focused on medium access and physical layer resources to reduce communication cost function. They updated operational state in physical layer and then focused on medium access and network layers for optimization which they collectively called network planning.

MOTIVATING SCENARIO

Transport of media in wireless networks is ever growing requirement in the real world. Figure 2 shows a motivating scenario which is related healthcare domain. There is wireless network that connects hospital, physicians patients and ambulance. When there is an emergency, there is need for take ultrasound and the related image needs to be sent to physician. If the transport of media is not perfect and Quality of Experience (QoE) is not good, physician will not be able to make well-informed decisions.

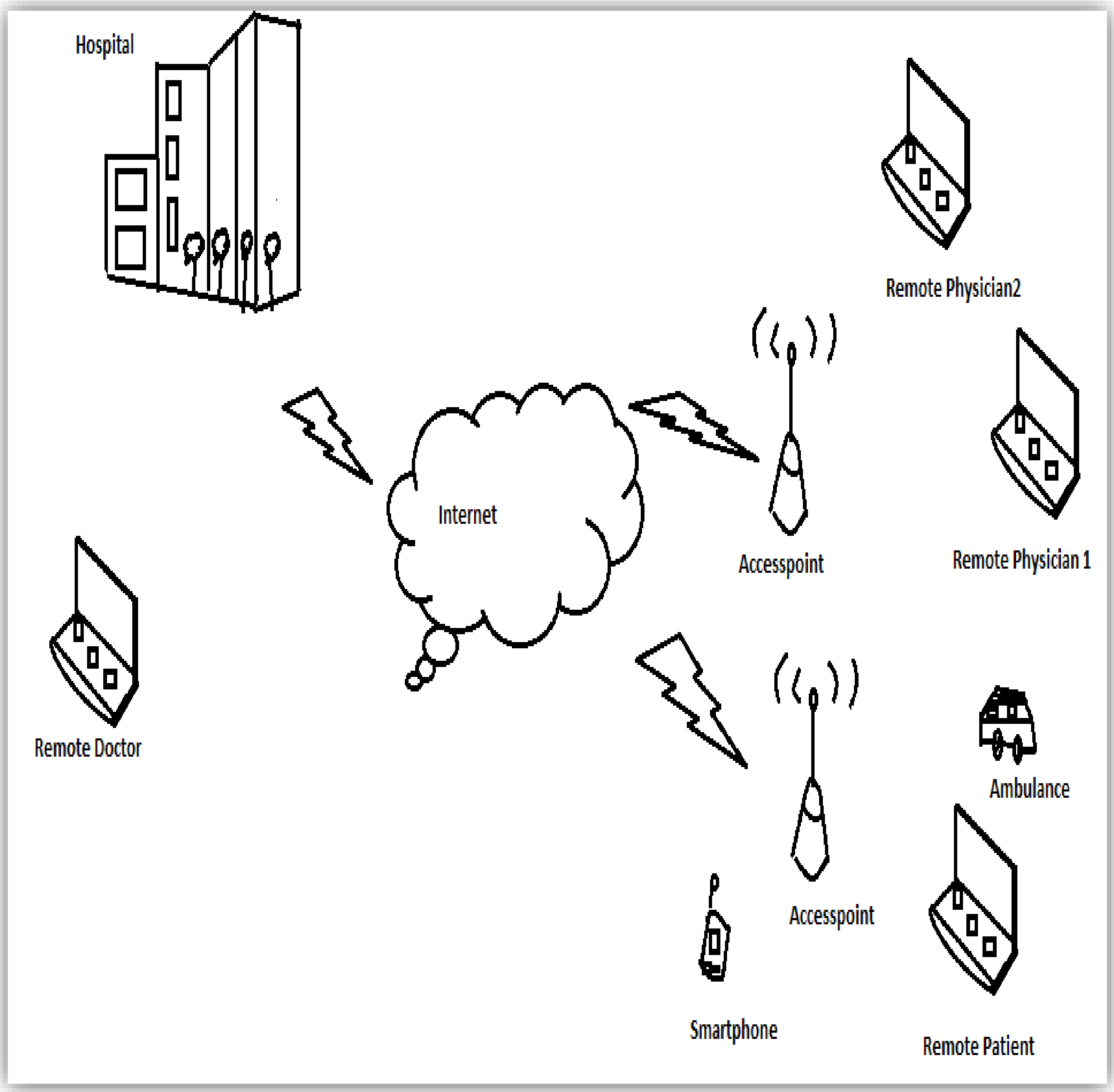

Figure 2 – Motivating scenario

When the video streaming over wireless network is improved using cross layered design, it is possible that QoE is improved and that will serve the purpose. This is the motivation behind taking up this research work. If the transport of media is not optimized in wireless networks, it will be of less use. On the other hand the well defined QoE when achieved can help speed up diagnosis and thereby improves quality of services in healthcare domain.

PROBLEM DEFINITION AND METHODOLOGY

In wireless communication applications, excessive delay and unreliable channel conditions are the two issues causing deterioration of quality in video transmission. And video transmission is a kind of inelastic flow that needs to be given high importance and high quality needs to be rendered. In the light of Universal Multimedia Access (UMA) emerging as next generation of multimedia applications, optimization of video transport in wireless networks using cross layer design approach is inevitable. On the other hand the optimization of individual layers is not an ideal solution as it leads to suboptimal performance. In adverse conditions, wireless nodes need to adapt to the needs of multimedia applications in order to provide expected quality of service at the receiver end. According to Open System Interconnection (OSI) model [15] different layers such as physical layer, data link layer, network layer, transport layer, session layer, presentation layer and application layer are available. As explored in [16] there are many cross-layer design approaches namely top-down approach, bottom-up approach, application-centric approach, MAC-centric approach, and integrated approach. In case of top-down approach the upper layers dictate the QoS strategy for lower layers. In bottom-up approach the upper layers are configured based on the states of lower layers. Application-centric approach the optimization is in application layer which reconfigures other layers in either top-down or bottom-up fashion. In MAC-centric approach the MAC layer takes requirements from application layer and optimizes its own parameters and that of physical layer for better optimization. The integrated approach focuses on taking an optimal decision based on the information, requirements and parameters received from different layers.

MAC and physical layers are widely used in the literature for cross layer design. In this research we used them by considering as optimization problem. We improve MAC layer functionality and physical layer functionality as per the requirements of application and produce high quality video streaming. In physical layer Adaptive Modulation is used while in the MAC layer the following improvements are made.

1. In MAC layer the properties of packets are made dynamic so as to assign priorities of packets based on hop length information and laxity. Thus it can improve Packet Delivery Ratio (PDR) even under heavy workloads.
2. Another important improvement in MAC layer is that transmission opportunity (TXOP) is used adaptively. In other words the time interval is appropriately used for initiating transmissions. Thus the scheme can reduce the number of accesses to channel for transmitting large number of video frames.

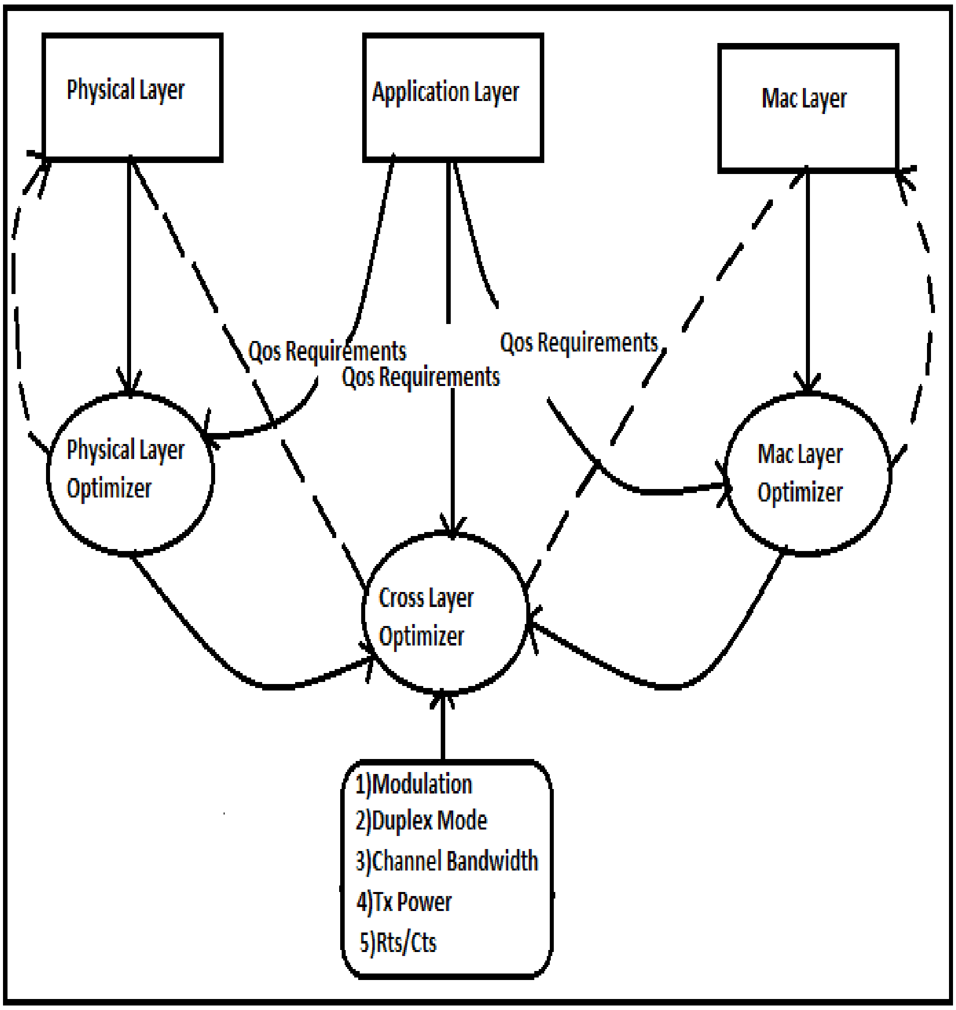

Figure 3 – Overall cross-layer design approach

As shown in Figure 3, the cross layer design is briefly described here. However, this paper is confined to the implementation of physical layer improvements only. The MAC layer enhancements and cross layer realization are deferred to our next two papers in the series respectively. Physical layer optimizer and MAC layer optimizer take QoS requirements with respect to video streaming quality from physical layer. These optimizers provide the enhancements back to respective layers for improved performance. The two optimizers are also considered by the cross layer optimizer which considers modulation, duplex mode, channel bandwidth, TX power and RTS/CTS. The cross layer optimizations are reflected back to physical and MAC layers for reaping benefits of joint optimization.

PHYSICAL LAYER OPTIMIZATION

Physical layer is the first layer and the lowest layer in OSI model. Its implementation is also known as PHY. This layer has logical data structures that are used for the high level functionalities of network. This is the most complex layer due to plethora of hardware technologies available in market. This layer defines how raw bits are transmitted in the network. The notion of code words is used to group bit streams. The PHY layer provides mechanical, electrical, and procedural interface for data transmission. The modulation scheme used in this layer can influence the performance of the PHY layer. An optimizer is built in order to reconfigure physical layer with respect to its modulation scheme. A modulating signal is something that carries information that needs to be transmitted. In the telecommunications terms, the modulation is process of conveying a message signal such as analog audio signal or digital bit stream which is inside another signal in order to get physically transmitted. The optimizer built for physical layer alters modulation process based on the QoS requirements obtained from application layer. In other words the PHY layer is reconfigured by the optimizer in order to cope with QoS needs as much as possible. The conceptual flow of the optimization is shown in Figure 4.

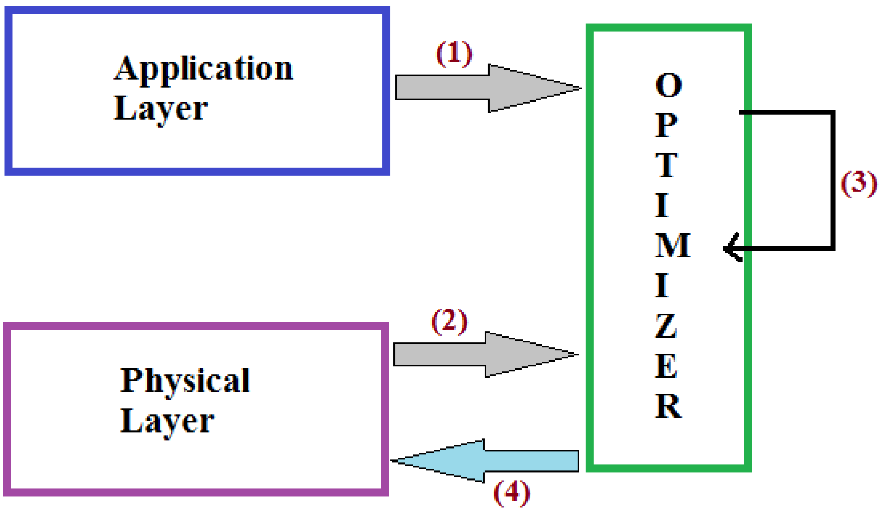

Figure 4 – Physical layer optimization

The optimizer takes QoS requirements from application layer and the current configuration details from the physical layer. Then the optimizer reconfigures the modulation process of the physical layer based on the QoS needs. Then the physical layer gets the results of reconfiguration and it works accordingly to enhance its modulation process in tune with the QoS needs. Thus the physical layer is optimized. Modulation defines the way a stream of bits is transferred using carrier wave (Equation 1) with specific frequency and bandwidth. The carrier wave is studied and decision is made based on the QoS needs.

$$s = A\cos(2\pi ft + \emptyset) \qquad (1)$$

By modulating amplitude (A) or frequency (f) or phase (∅), the required QoS is achieved to the extent possible. This kind of modulation change, in PHY layer, results in the optimisation of multimedia transmission over wireless networks.

Notations Used

Notation	Meaning
Pe	Probability of error
x	Number of bit errors
Nbit	Number of bit errors tolerated
error	Holds true if there is bit error

Proposed Modulation Technique

We employed binary phase shift keying approach for modulation to improve QoS in transmission of multimedia content.

```
Input: probability pr
Output: Optimized modulation
Initialize Pe
Initialize x
Initialize error to false
Initialize nbit to zero
IF nbit=0 THEM
  Compute Pe based on pr
ELSE
  Compute Pe based pr and nbit
END IF
IF x<Pe THEN
  error=1
ELSE
  error=0
END IF
IF error=1 THEN
  Optimize modulation
END IF
```

As shown in the modulation technique, it is evident that finding probability of bit error is playing an important role in optimization of modulation in PHY layer. The optimization is done for improving throughput in order to reach QoS needed by applications over wireless networks.

PERFORMANCE METRICS

Existing performance metrics such as throughput, packet delivery ratio and end to end delay are used to evaluate the efficiency of the proposed physical layer improvements for improving quality of service of network. These metrics are briefly described in the following sub sections.

A. Throughput

It is the measure used to know the amount of data transferred from one node to another in a given time period. It is computed as follows.

$$\text{Throughput} = \frac{\text{No.of Bytes Recieved}}{\text{Simulation Time(s)}}$$

B. Packet Delivery Ratio (PDR)

This is the measure to know performance of wireless network. It is the ratio of packets sent and packets received. It is computed as follows.

Packet Delivery Ratio = Packets sent ÷ Packets received

C. End-to-End Delay

This measure reflects average time needed by a data packet to reach destination. It considers delays such as queuing delay, route discovery time, and buffering delay. It is computed as follows.

End-to-End Delay = Total time spent to deliver packets / number of packets received

SIMULATION RESULTS

While making simulation experiments on video streaming using single layered approach (physical layer improved) many observations are made with respect to performance of the proposed system. The observations include end to end delay, packet delivery ratio (PDR), and the amount of data transmitted. The results when compared with an existing system showed significant performance improvement. The simulation environment used for the study is as shown in Table 1.

Table 1 – Shows simulation environment

S.No.	Parameter Type	Parameter Value
1	Channel Type	Wireless Channel
2	Radio-Propagation	Propagation/TwoRayGround
3	Network Interface	WirelessPhy
4	Interface Queue Type	DropTail
5	Antenna Model	OmniAntenna
6	Interface Queue Length	50
7	Routing Protocol	DSR
8	rxPower	1.08918e-9
9	txPower	4.4613e-10 (250W)
10	RXThresh	1.4613e-10 (160m)

The simulation parameters used in NS2 for implementation of single layered approach for video transmission quality enhancement include DSR routing protocol, wireless channel as channel type, WirelessPhy as network interface and so on. They are presented in Table 1.

Table 2 – Results of end to end delay

Simulation Time	Delay Time (ms)	
	Proposed	**Existing**
0.0	0	0
5.0	0	0
10.0	0	0
15.0	0	10
20.0	0	11
25.0	0	0
30.0	0	0
35.0	0	0
40.0	50	250
45.0	200	100
50.0	80	0
55.0	20	50
60.0	50	150
65.0	10	100
70.0	0	0
75.0	0	0
80.0	0	0
85.0	0	0
90.0	0	0
95.0	0	0

As shown in Table 2, it is evident that there is significant performance improvement between existing system and proposed system in terms of end to end delay performance. Simulation time is measures in seconds. It is taken from 5 seconds through 95 seconds. With the proposed system 0 milliseconds delay is recorded from simulation time 5 through 35 seconds. Delay from 10 milliseconds to 200 milliseconds range is reported between simulation times from 40 through 65. Afterwards 0 milliseconds delay is recorded till 100 seconds of simulation. Similar kind of trend is there with existing system also. However, the delay time of existing system is significantly more when compared with that of the proposed system.

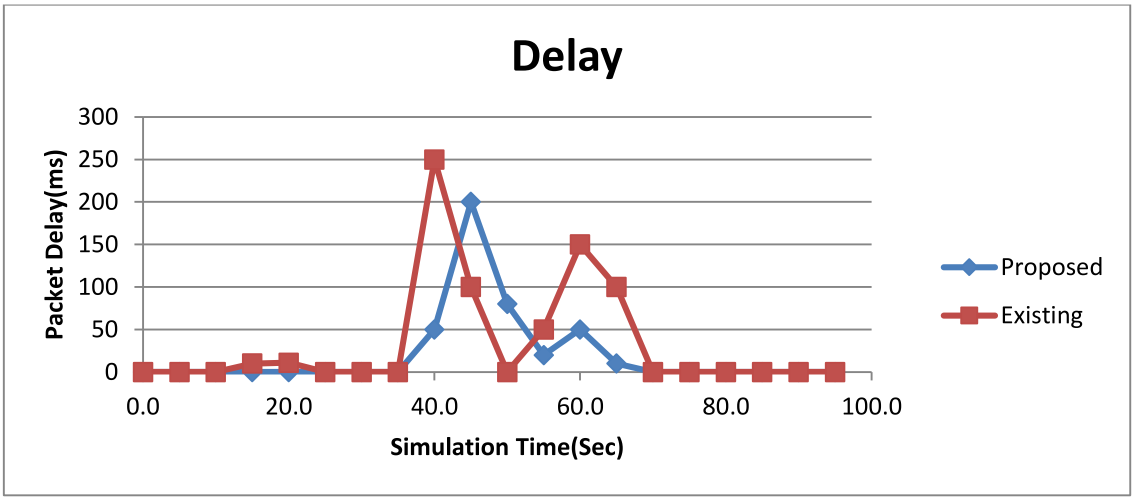

Figure 5 – End to end delay performance comparison

As shown in Figure 5, the horizontal axis represents the simulation time in seconds while the vertical axis represents end to end delay performance exhibited. The results revealed that the proposed system and existing system have same performance to some extent up to 35 seconds of simulation time. Afterwards, interestingly, the proposed system showed significance performance improvement. Similar trend is with the existing system. However, the performance of the proposed system at all simulation points where more than 0 milliseconds is recorded is significantly better.

Table 3 – Packet delivery ratio performance comparison

Simulation Time (Sec)	Packet Delivery Ratio	
	Proposed	**Existing**
0.0	0	0
5.0	0	0
10.0	0	0
15.0	0	0
20.0	0	0
25.0	0	0
30.0	0	0
35.0	0	0
40.0	0	0
45.0	0	0
50.0	0	0
55.0	1	0.5
60.0	1	0.5
65.0	1	0.5
70.0	1	0.5
75.0	3	1.5
80.0	3	1.5
85.0	5	2.5
90.0	8	3.5
95.0	9	4.5

As shown in Table 3, the results revealed that the proposed system has significant performance improvement over existing system in terms of packet delivery ratio. The simulation time considered is from 5 seconds to 100 seconds with gradual increase of 5 seconds. The observations revealed that till 50 seconds simulation time both the schemes shows same performance. Afterwards, the proposed scheme started showing improved performance over the existing scheme significantly.

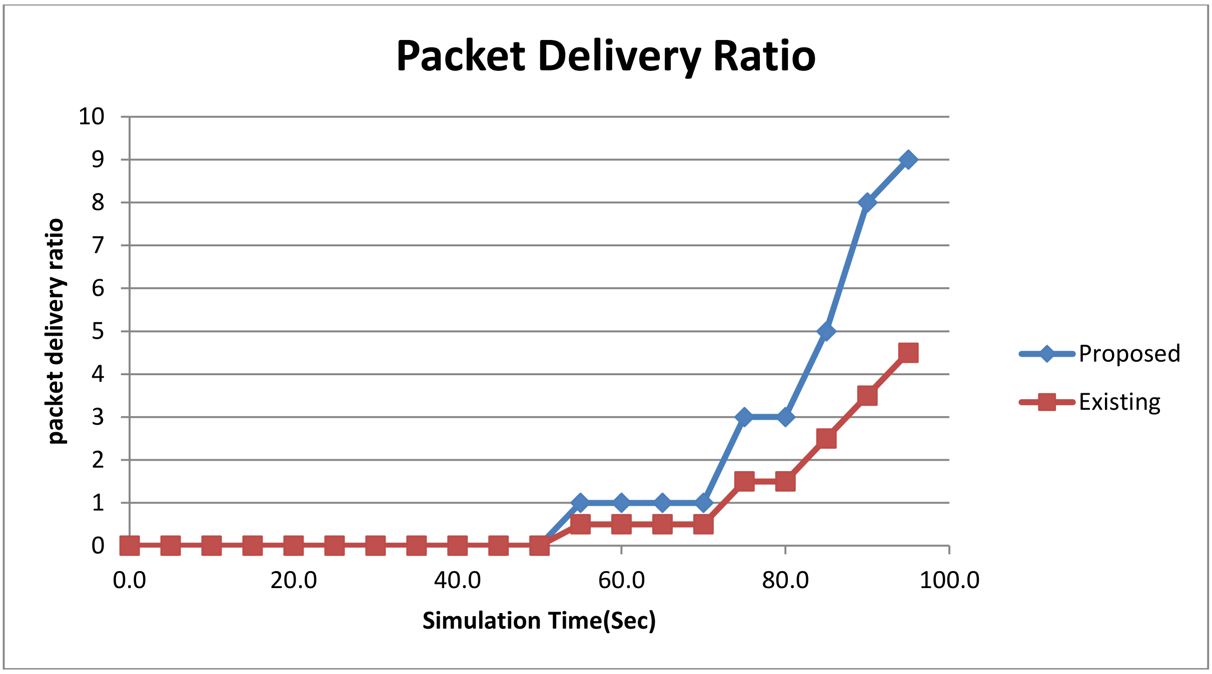

Figure 6 – Performance comparison of PDR

As shown in Figure 6, the performance of the proposed method with respect to PDR is compared with that of existing method. The horizontal axis represents simulation time in seconds while the vertical axis represents PDR value. The results revealed that the proposed system has comparable performance improvement as simulation time is increased. From simulation time 50 through 95, the proposed system shows improved throughput over the existing system.

Table 4 – Throughput performance comparison

Simulation Time (Sec)	**Throughput**	
	Proposed	**Existing**
0.0	0	0
5.0	0	0
10.0	0	0
15.0	0	0
20.0	0	0
25.0	1968	1513
30.0	2679	1842
35.0	3658	2534
40.0	4256	3246
45.0	7829	5249
50.0	12758	9125
55.0	13500	10241
60.0	14697	11254
65.0	15987	12473
70.0	24256	18246
75.0	38304	28456
80.0	42596	31459
85.0	43792	34219
90.0	39568	37159
95.0	37024	35156
100.0	43792	37456

As shown in Table 4, the throughput performance of Existing and proposed systems is provided. The proposed system shows significant performance improvement over the existing one. The simulation time from 5 through 20, throughput is not yet recorded for both the approaches. The throughput is recorded for both the schemes from simulation time 25 through 100. As the simulation time is increased, the throughput of the schemes is also increased. However, the proposed scheme showed significantly better performance over the existing one.

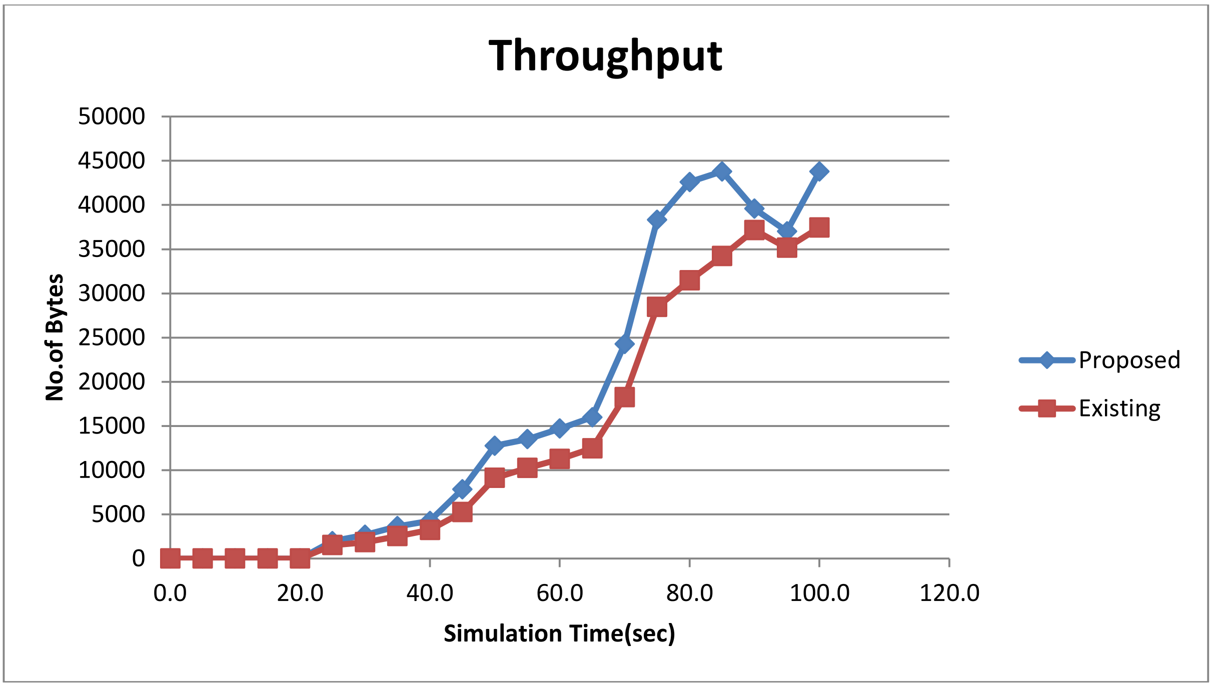

Figure 7 – Data transmission performance comparison

As shown in Figure 7, the performance of the proposed method with respect to data transmission is compared with that of existing method. The horizontal axis represents simulation time in seconds while the vertical axis represents the number of bytes of data transmitted. The results revealed that the proposed system has comparable performance improvement as simulation time is increased. Two trends are observed in the results. First, there is performance improvement in terms of throughput as simulation time is increased from 25 seconds through 100 seconds. Second, the proposed scheme showed significantly better throughput performance over the existing one at every simulation time at which throughput is recorded.

CONCLUSIONS AND FUTURE WORK

In this paper, we studied the problem of transportation of media in wireless networks. With respect to multimedia applications there are many aspects such as spectrum utilization, power consumption, multimedia quality and implementation complexity to be considered. As these are associated with different layers of OSI model, we proposed a cross layered approach which focused on improving physical and MAC layers. However, we implemented only physical layer changes in this paper. In physical layer Adaptive Modulation and Coding is used to enhance transport of media. We made NS2 simulations to realize the intended results in the process of transport of media. The simulation results revealed that the proposed approach has comparable performance improvement over existing system. In future we intend to improve MAC layer and then realize joint optimization using cross-layered approach for maximizing performance of transportation of media in wireless networks.

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