IMPLEMENTATION AT TCP/IP IN CROSS LAYER DESIGN

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***Abstract*: Wireless Sensor Networks are made up of large number of sensing nodes having computing and communication capabilities. A network has various protocols that help in efficiently communicating between these nodes. TCP/IP networks have end to end connections established with the help of five layers which are designed to maintain a limited interface with their neighboring layers. The encapsulation of information among these layers results in side effect on Quality of Service (QoS), latency, extra overload, etc. Here comes the emergence of Cross Layer Design (CLD) in Wireless Sensor Networks. Cross Layer Design helps in sharing information among all the five layers to improve wireless network functionality, mobility, Quality of Service (QoS). It helps in enhancing the performance of already existing architectures by enabling interaction between different non-adjacent nodes also. It helps in increasing the efficiency of the network and network throughput. In this paper, various cross layer design characteristics, classifications are explained. The need for CLD in WSN is also shown.**

I. INTRODUCTION TO CROSS LAYER DESIGN IN WIRELESS SENSOR NETWORKS

Wireless Sensor Networks and Cross Layer Designs, both are emerging trends. A lot research is being presented in different papers regarding WSN showing interaction between various non-adjacent layers of the network stacks by implementing CLD [1][2]. The black box aspects of the network results in the extraction of internal details of each layer, which leads to information hiding. The major aim of cross layer design is to enhance the performance of the system and get the desired Quality of Service (QoS) required for the various applications. The implementation of CLD can result in increasing the network efficiency and optimizing the throughout. The CLD in WSN is very useful, energy efficient, scalable and secured in comparison to the traditional approaches. [3] Cross layer designs examine the inter relationship and reconfiguration of the network layers to identify and improve the connection failures that might arise in the root. Cross layered approach helps in reducing the overhead by sharing data between different layers; this is because the protocol stack is treated system instead of independent layers which was in traditional approach. The implementation of cross layered architecture results in increasing network flexibility, interoperability and maintainability.

Cross layer design is a way that helps in breaking the traditional waterfall concept that was considered in common network protocols. A lot of research and solutions are achieved to overcome this problem from which cross layer design is most efficient one. Cross layer design does not destroy the layer structure of the network. It arrange the inter layer communication between non-adjacent layers also. With the help of cross layer design, the internal status and parameters of each layer can be revealed to the other layers resulting in removal of redundancy. Also, CLD helps in definitive the behavior of other layers by retrieving and receiving the data from them. Hence there is a splitting the parameters, status and information among all the layers without any effect on the layer structures of the network

II. CHALLENGES OF CROSS LAYER DESIGN

In cross layer design, there is different manner for the communication among the layers, that results in two major challenges that the cross-layer design has to deal with: Co-existence and Signaling. Another major concern in cross layer design is the extra overhead that arises due to the exchanging of information among the cross layers. There is no uniform cross layer design that can be used for all the applications, as different applications have different requirements of the design. The role of physical layer in a wired network is to receive and send packets but in wireless networks, physical layer plays a main role. CLS's relaying on advanced signal processing at physical layer. Also, cross layer design violates the encapsulation policy of the layers resulting in destruction of well-organized layered structure into a flat and disorganized architecture. It is very difficult to modify one layer without seeing the other layers in cross layer design. So, the fundamental disadvantage of cross layer design is the destruction of cross layered architecture.

There are a few open challenges that a designer keeps in mind while introduce a cross-layer design [5]:

- How do different cross-layer design proposals coexist with one another?
- Will a given cross-layer design idea possibly stifle innovation in the future?
- What are the cross-layer designs that will have most significant impact on performance of a network and hence should be most closely focused on?
- Has a given design proposal been made with a thorough knowledge of the effect of the interactions between parameter at different layers on network performance?
- Under which network and environment condition would a particular cross layer design proposal be invoked?

- Can the mechanism or interfaces used to share information between the layers be standardized? What should be the role of physical layer in a wireless network?

There are certain challenges faces by Wireless Sensor Networks in term of QoS:

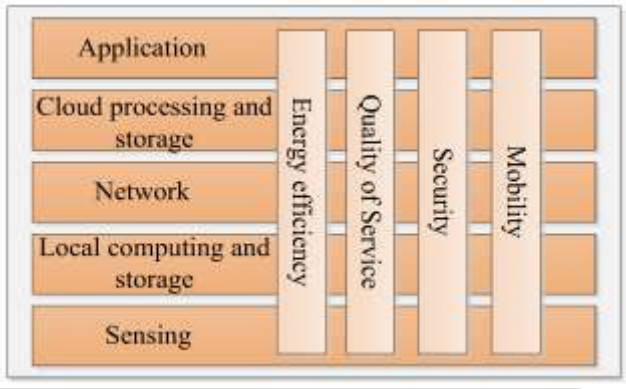
- Limited Resources Wireless sensor nodes have very small memory and battery life.
- Traffic Asymmetry Traffic near the sink node is high as compare to the remaining network areas.
- Scalability Sensor network has millions of nodes and nodes can be added or put to sleep mode time to time.
- Heterogeneous Traffic Sensors nodes collect different types of data from the environment and these data are in different formats.
- Security

III. GOALS OF CROSS LAYER DESIGN

The three major target that need to be considered while designing cross layer architecture are QoS, security and mobility. A cross layer design scheme essentially aims at fulfilling at least one of these three goals. Fig. 2 illustrates the coordination model having three coordination planes (Security plane, QoS plane and mobility plane), extended over the five TCP/IP protocol layers. [6]

A. Security: The security coordination plane implements the protocols that are concerned with the security issues among the five layers of TCP/IP protocols. Different encryption methods like Wi-Fi protected access must be deployed to perform secured communication across the cross layered design. Various encryption methods might be deployed at application layer like end to end encryption, at network layer and/or data link layer and physical layer help to achieve secure communication in cross layer design.[7][8]

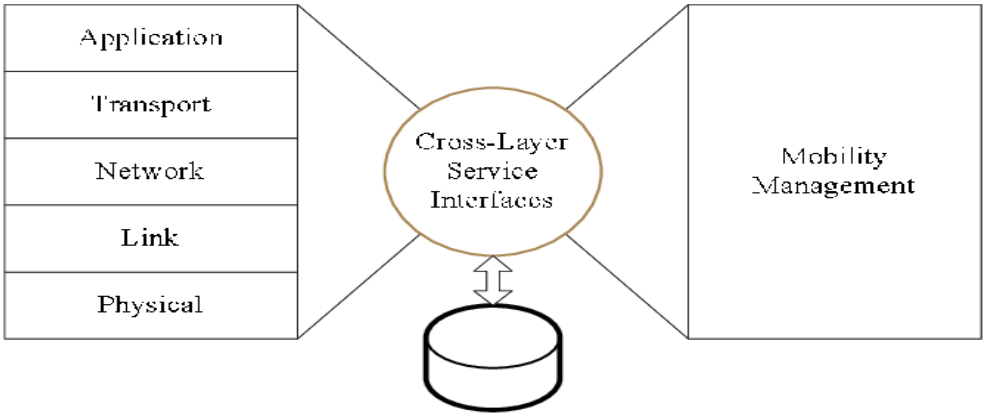
B. Quality of Service (QoS): The main aim of QoS coordination plane is to arrange high quality of service in the wireless communication across five layers. In the wireless networks to get upgraded quality, upper layers must be aware of the information and component of the two lower layers (physical layer and data link layer) [39]. This direct sharing of information among the upper three layers and lower two layers is not possible in the traditional waterfall like concept of wireless network model. Hence, the QoS coordination plane helps in achieving the improved QoS communication in cross layer design. [9]



In wireless networks, most of the applications use TCP protocol at transport layer which is very sensitive to the problems in physical and data link layer. The various issues can be: channel fading resulting route scheduling, transmission delay or high bit error rate that may require retransmission, too many retransmissions may cause congestions. Hence with the improvement of Qi's, by cross layer designs, these problems can be solved easily.

C. Mobility: This coordination plane helps in guarantying an uninterrupted communication in wireless networks. Nodes in wireless sensor network can be stable or mobile in nature [39]. For the mobile nodes, the events like channel switch or route change must be discovered and solved to get uninterrupted communication during the session. There are two division of hand-over discussed in [8]: horizontal handover and vertical handover. In horizontal handover, the movement of nodes is among different access points of the same wireless access technology. While in vertical handover, the nodes are moving between access points of different wireless technologies. In both these categories, the events like channel switch and route change must be informed to the upper layers, so that the communication remains uninterrupted even if there is a change of events at lower layers. Channel fading, high bit error rate, transmission delay, etc. may also alter the mobility as well as QoS. For example, in centralized networks like cellular networks, there are a finite number of users that are served because of finite number of channels available. Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) are used to solve these problems. But these two techniques result in waste of time slots and bandwidth whenever there is no data transmission between the base station and the mobile station. So, cross layer design helps to overcome these complication. The Passenger Information System (PIS) provides the passengers in the metro trains with real-time dynamic multimedia information like live news, live matches, train schedules, forecast etc. In case of any natural disaster and accidents, this system also provides knowledge regarding safety and evacuation. Video communication network is a major sub system in metro PIS. A high-quality video information transmission between high speed train and ground gives the

passengers a comfortable journey when they commute. Unfortunately, old WLAN's were not designed for high speed environments resulting in poor QoS. Whenever a train moves away from one access point and enters the coverage of another access point, moving from one station to another, there takes place a handover of communication resulting in interruption and long latency. Because of highly compressed video signals, in wireless metro environments, video communication gets extremely vulnerable. Despite of multiple optimized models being proposed to get better quality video transmissions over loss channels, most of them focus on improving the transmission performance. An integrated design way to optimize application layer QoS for video transmission in metro PIS is designed. To optimize the video transmission QoS in highly mobile environments, IEEE 802.11p network and fountain codes are used at application layer. [6]



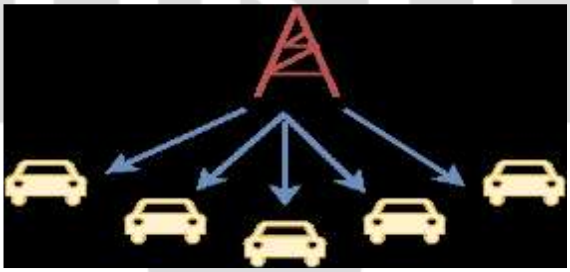
CLASSIFICATION OF CROSS LAYER DESIGNS

Depending upon the sharing scheme inside one node, we can organise the design into manager method and non-manager method.

A. **Non-Manager Method:** In this method, a direct communication between the pair of layers is allowed. There is no change in the design of the network model layers. The only change that occurs is in the functionality of the protocols in certain layers by allowing the direct communication between two layers. Fig 3. Shows a model of non-manager method.

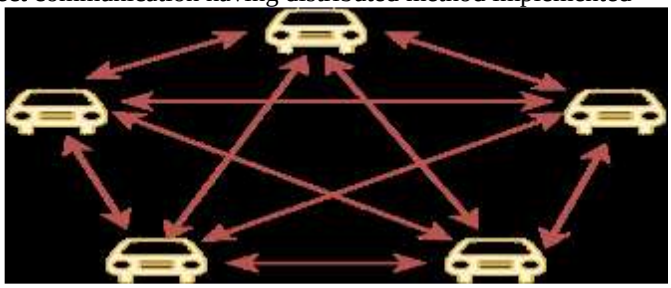
B. Manager Method: In this, a vertical plane acts as a manager that is used to share the data with all or some layers of the protocol stack. In this, there is no change in the structure of the model layers but, there is a change in the functionality of the layer protocols that allows them to share the data with the vertical plane. Fig 4 shows the manager method in which, the vertical plane is used to share information with the stack of the layers. Depending upon the sharing scheme among the nodes in a network, we can divide the design into centralized method and distributed method.

1. Centralized Method: In this approach, a central node or a base station is introduced in a hierarchical manner. This central node is used to share and manage information sharing of the layers between two nodes. This method is basically adapted for cellular network. Fig 5. Shows the centralized method.



Centralized Method

2. Distributed Method: In this approach, the information is shared using the organization of the network. In this method, there is not central node to manage and share information. All the nodes directly share the information with other nodes and mange individually. Fig 6. shows the direct communication having distributed method implemented



Distributed Method

CROSS LAYER IMPLEMENTATION AT TCP/IP

WSN has generally been used in military applications, crisis response, medical area etc. Each sensor node plays a important role of being a terminal and a router under the assumption that they do not communicate directly with each other. Various topologies are existing in WSN Multiple protocols are implemented to get efficient and economical routing path for communication among them. Mostly applications are dependent on TCP for communication. In TCP/IP protocol there are five layers. Each layer coordinate with the layer above it and layer below it. Because of Transmission Control Protocol (TCP) of transport layer and Internet Protocol (IP) of Network layer, TCP/IP model is most desirable for quick and efficient communication. TCP/IP model consists of five layers: application layer, transport layer, Network (NET) layer, Data Link (DL) layer and Physical layer. [10]

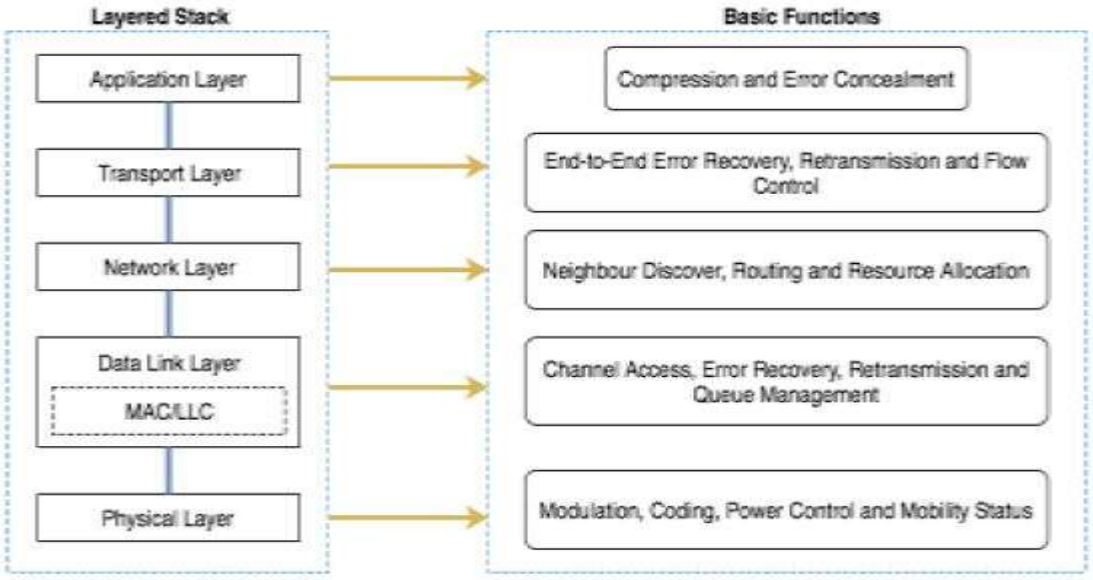


Fig. 7 Layered Stack and main functions of each layer [13]

Fig 7. Shows the layer structure of TCP/IP model. The functions of each layer are discussed briefly:

A. Physical Layer: This layer focus on physical devices and transmission media. It gives multiple antenna gains and improves integrity and throughput of data transmissions. This is the layer important for coding and modulation implementations. Also, it adjusts the transmitting power and controls the effects of mobility and propagation effects.
B. Data Link Layer: It is the media access layer, helps in error recovery, maintain retransmissions and queuing of packets. It is further classify into two sub layers: Medium Access Control (MAC) sub layer and Logical Link Control (LLC) sub layer.

C. Network Layer: The main responsibilities of this layer are to discover the neighbors, routing and allocate resource functions. The main part is routing in which it guides the packet in the network from source to destination. There are multiple routing protocols designed to satisfy the requirements of Wireless networks. These protocols can predetermine the performance on the bases of packet loss ratio, end to end delay and network throughput.

D. Transport Layer: The main function of this layer is to control congestion, do error recovery, flow control, packet sequencing (reordering) and end-to-end connection setup. It also helps the application layer in mapping and allocating the flow to routes which are found at network layer.

E. Application Layer: This layer acts as an interface between the end user and the TCP/IP model. It considers the requirements of the end users and divides the services into multiple categories like real time services or non-real time services, multimedia services etc.

As cross layer design requires more interaction among the layers as compared to the one shown in fig 7 which has just the interaction among the adjacent layer only. Therefore, it disrupt the layered architecture of the model. Cross layer design requires information exchange of layer with every other layer as well as versatility to this information by each layer. This type of design results in more robust structure.

The cross-layer solutions for the problems in the layered architecture are listed below:
A. **Layer-centric Solution:** In this a certain layer acts as a central layer that helps to control the cross-layer adaptation by accessing the internal parameters and algorithms of other layers. Despite of significant improvement in the systems performance by this method, still the layer structure is ruined because of the need to access the internal parameter of the other entire layer.

B. **Centralized Solution: A** centralized optimizer is used for estimating both the availability of resources and the environment dynamics, this optimizer can be a middleware or a system level monitor. In this approach, each layer forwards its information, complete protocol parameters, characteristics and algorithms to the central optimizer. Each layer also must obey the instructions requested by the central optimizer. Unfortunately, this method also violates the layered architecture

NEED FOR CROSS LAYER DESIGN IN WIRELESS SENSOR NETWORK

The concept of cross layer design was first recommended for the wireless links deployed using TCP/IP networks. The basic concept of cross layer design was transfer of parameter information between two or more layers to get correct result. There are distinct kinds of wireless sensor networks each having distinct set of problems [40]. The major challenge is quality of service at application layer. Congestion is one of the most difficult problems faced in wireless sensor networks which results in wastage of huge amount of energy due to multiple retransmissions that takes place because of packet dropping. There are two kinds of congestion that can appear in sensor networks: Node level congestion and link level congestion. In node level congestion, the packet arrival rate exceeds the packet service rate which results in buffer overflow and packet loss. This also increases the queuing delay. In link level congestion, collision appear when multiple active sensor nodes try to exceed the channel at same time. Hence it is relevant to several nodes sharing same wireless channel. There is a need to implement cross layer design in wireless sensor networks. Some of the parameters that can be enhance by cross layer design are discussed below: A. Throughput There are many causes that affect the throughput of wireless sensor networks. The major causes that affect the data throughput are limited connectivity and Medium Access Control (MAC). The main requirements of the MAC protocol are minimum latency and high throughput. Each node, routes their packet towards the sink node. Hence, the nodes that are placed near the sink node will have high volume of load as compared to the remaining nodes in the network. These heavy load nodes will be consuming more energy and high congestion in large networks. The area near the sink node has significant collisions and packet loss. B. Quality of Service (QoS) The major parameters to get desired quality of service are resource constraints like bandwidth, buffer size, energy that helps in determining the quality of performance and manage the resources. Also, time delay, data redundancy, topology of network, heterogeneity of nodes, distributed network affects the Quality of Service. C. Resource constraint there is finite number of resources in wireless sensor network. Distinct resources like energy, memory, bandwidth, buffer size, etc. are scarce in network. Power constraint is a primary issue in wireless senor network. If one or more nodes in Wirelesses sensor networks reaches a low-level energy, the while network may compromise its performance. One of the approaches for efficient energy consumption in WSN is discussed in [12]. In this orthogonal modulation and CAODV routing protocol is used to get better result scalability There are millions of sensor nodes set up in wireless sensor network applications. These large amount of sensor nodes have a potential impact on the hardware components and might affect its communication bandwidth and storing capabilities. Each protocol in these kinds of networks must be scalable and simple. The network middleware should also support scalability. E. Security In wireless sensor networks, the node senses the physical environment directly. Hence security is a main challenge to both the nodes and the network. Different attacks are possible at different layers. For example, collision at data link layer, false routes at network layer, jams at physical layer, etc. Some other parameters that can be optimized by Cross Layer Design approach are: Network Lifetime, Node distortion, Mobility, Heterogeneity, Accuracy, Latency, Functionality etc. [11].

CONCLUSION

In dynamic environment, implementation of a potential cross-layer design can improve the energy efficiency, reliability of packet deliver and stability of multi-hop. There are several factors other than energy efficiency in WSNs that have been discussed in this paper. The paper concludes the general discussion about implementation of cross-layer design in wireless sensor networks. It highlights the various challenges faced in this implementation and the desired solutions for these problems. The paper highlights the major cross-layer design approaches with their advantages and disadvantages. Some of the parameters that show the need of implementing CLD in WSN have been described. Furthermore, the paper discussed certain drawbacks of cross layer design and mentioned various researches that are providing solution to overcome those. The paper also endeavored some open challenges that can be addressed in future research works.

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