CURRENT TRENDS AND FUTURE ASPECTS IN CROSS-LAYER DESIGN FOR THE WIRELESS NETWORKS

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ABSTRACT

Computer network today are becoming popular day by day in our day to day life. The users are looking forward to use wireless technologies such as Bluetooth, WLANs based on the IEEE 802.11 Standards etc. that allow them to share information via wireless media. The user can access the network to communicate with each other anywhere and anytime using the communication devices. The wireless network has several advantages over the wired technologies like flexibility, mobility, cheaper and faster deployment, easier maintenance and upgrade procedures. Cross-layer design refers to protocol design done by actively exploiting the dependence between the protocol layers to obtain better network performance in terms of throughput, average end to end delay etc.. In this paper, we are providing a survey of different cross-layer proposals for wireless networks taking in account the ongoing research in this hot area. This article brief the readers an overview of cross-layer concept while discussing different cross-layer proposals given by researchers.

KEYWORDS

Cross-layer, Cross-Layer Design, Cross-Layer Optimization, Cross-Layer Framework, Wireless Network

1. INTRODUCTION

Wireless technologies offer mobility to the users due to which they are indispensible part of our daily life. As the number of the users is increasing day by day and the wireless channel is open to the potential intruder, the security of the message is the major concern. The broadcast nature of the wireless networks has raised considerable security issues. The devices used in the wireless network are low cost devices and easily available to the intruders and hence the potential intruders who has some technical skills can modify or alter the messages. If the intruder is within the range, it can listen to the unintended information. Although many security algorithms exist on the upper layer of the protocol stack such as Data Encryption Standard (DES) [1],[2][3],[4], Advance Encryption Standard (AES) [5],[6],[7],[8], Wired Equivalent Privacy (WEP) [9], [10],[11],[12], Wi-Fi Protected Access (WPA) and WPA2 [11],[13],[14],[15],Extensible Authentication Protocol (EAP) [16],[17],[18],[19], Extensible Authentication Protocol-Transport Layer Security (EAP-TLS) [20],[21],[22], Extensible Authentication Protocol-Tunneled TLS (EAP-TTLS) [23],[24],[25], IP-Security (IPsec) [26],[27],[28] and Secure Socket Layer (SSL) [28],[30],[31], exist to provide security, still there is a need of more secure, robust and reliable security algorithm. As per as the architecture is concern, it plays a vital role in the designing of a

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system. Architecture in system design pertains to breaking down the system into modular components systematically specifying the interactions between the components. The significance of the architecture is difficult to exaggerate. Modularity provides the abstractions needed for the designer to understand the overall system. With the abstraction of the system it is easy to develop and design it concurrently with fewer efforts. Designers can focus their effort on a specific part with a assurance that the entire system will be assemble by joining all the subparts and will interoperate. A good architectural design can thus lead to quick proliferation. On the other hand, taking an architectural shortcut can often lead to performance gain. Thus there is always a fundamental tug-off between the performance and architecture and there exist a temptation to violate the architecture. However, architecture can also be regarded as performance optimication, although it takes a longer span of time.An architecture that allows enormous proliferation can lead to very low per-unit cost for a given performance. This lead to a trade-off between the realization of short-term vs the long-term gains.The most famous architecture is the OSI Model and the well known TCP-IP Model.The OSI Model consists of seven layers viz. Application layer, Presentation layer, Session layer, Transport layer, Network layer, Data Link layer and Physical layer. However the TCP-IP consists of five layers in which the upper three layers of the OSI model is merged as a superlayer "Application layer".

Traditionally, network protocols are divided into independent layers. Each of these layers is designed separately and the interactions between these layers are performed with the help of well defined interfaces. In the layered architecture, UDP packets are sent to and fro from the network layer to the application layer via the transport layer. This communication causes some avoidable delay which degrades the overall performance of the network. If we can design a direct application layer- network layer interface bypassing the transport layer, we can save the end to end delay [40] and hence the overall network performance can be improved. Designing such interfaces is a cross-layer communication. Cross layer design refers to protocol design done by actively exploiting the dependence between the protocol layers to obtain better performance gain [32]. This is unlike the layered architecture where the protocols at the different layers are designed independently and do not depend on the other layer protocol. In the layered protocol stack each layer communicates only with the adjacent layers using well defined interfaces and hence there is no performance optimization. Performance optimization can be obtained with the help of adaptation and optimization using the available information across many protocol layers.
In a layered architecture, the designer has two choices at the time of the protocol design. Firstly protocol can be designed by respecting the rules of the reference architecture i.e. designing a protocol such that the higher layer protocol only make use of the services at the lower layers and is not concerned about the details of how the service is being provided. Secondly, protocols can be designed by violating the reference architecture, for example by allowing direct communication between protocols at the nonadjacent layers. Such violation of the layered architecture is cross layer design with respect to the reference architecture.

The most fundamental and conceptual challenge in any network design is how to allocate the available resources among the different network users. The conventional approach to network protocol stack design has always been to treat the different layers as separate entities, and then perform layer specific operations on these entities to achieve an operational network stack with adequate and satisfactory performance. The layered protocol stack design is highly rigid and firm, and each layer only takes care about the layer directly above it or the one directly below it. This results in non-collaboration which exists between different layers, seemingly because no one at that time saw any need for such a non-collaborative design known as the cross-layer design. In the layered architecture, if a designer is working on the layer 2 protocol, he is independent of the protocols exists on layer 1 i.e. he has to do nothing with the layer 1 design. But if it is the case of the cross-layer design the protocol designer has to take care of the violations he made to the traditional design concept.

The paper is arranged in the following way: we begin in Section II, discussing the definition, motivation and different cross-layer proposals. In Section III, we are providing with different evaluating factors for any proposal. We present the open challenges and research areas in Section IV and the conclusions of this paper are briefed in section V.

2. CROSS-LAYER DESIGN IN WIRELESS NETWORKS

2.1 Definitions of Cross-Layer Design

Cross –layer design is said to be the violation of the layered architecture in order to get some improvements in the network parameters. In [32],[33], the authors defined the cross-layer design as follows:

Definition: Protocol design by the violation of layered communication architecture is cross-layer design with respect to the original architecture.

Comment 1: Violation of a layered architecture involves giving up the luxury of designing protocols at the different layers independently. Protocols so designed impose some conditions on the processing at the other layer(s).

Comment 2: Cross-layer design is defined as a protocol design methodology. However, a protocol designed with this methodology is also termed as cross-layer design.

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For example, let us consider a model in the fig.1 which consists of three layers viz. layer-1, layer-2 and layer-3 and follows the traditional layered architecture. Layer-1 is the lowest layer which provides its services to the layer-2 and layer-2 provide service to its layer just above it i.e. layer-3 via well defined interfaces which exists between layers. If we define a interface which can communicate directly between the layer-1 and layer-2 bypassing the layer-2 then it is the violation of the layered protocol and hence it is a cross-layer design. While doing this the designer must take care of the headers which are combined at the layer-2 (as layer-2 is responsible of various operations and convert the layer-1 frame as required by the layer-3 by adding its own header).

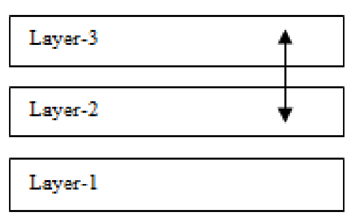

Fig.1. Cross-layer design between layer1-3

A big picture of the cross-layer deign in the wireless network can be seen in the Fig.2 which shows all the five layers in the wireless protocol stack.

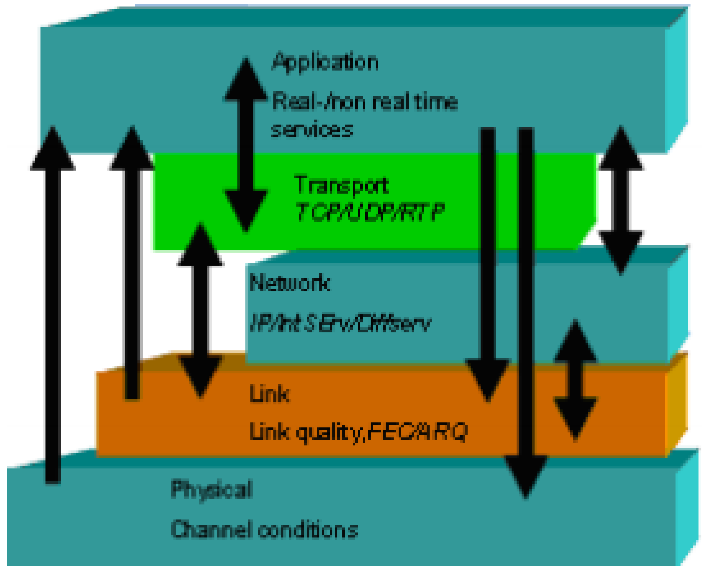

Fig.2. Cross-Layer for wireless protocol stack

2.2. Motivation Towards Cross-Layer Design

Cross-layer design emphasizes on the network performance optimization by enabling different layers of the communication stack to share state information or to coordinate their actions in order to jointly optimize network performance. It is a human mentality and psychology that if a new design paradigm is proposed, we compare it with the existing one. Hence the concept of cross-layer design must be compared with the traditional layered architecture so that people can be motivated towards the use of the violation of the layered design. For example let us consider the cross-layer design for ad hoc and sensor networks. The distributed infrastructure-less nature of ad hoc and sensor networks offers new challenges and opportunities for network designers, such as the distribution of network management across resource-limited nodes. To meet the unique and exclusive challenges of wireless ad hoc and wireless sensor networks and to utilize the limited node resources efficiently and reliably this concept of cross-layer design is used. Researchers have proposed some novel approaches and architectures that implicitly and explicitly violate the strict layered design, cutting across traditional layer boundaries.

In the following discussion we will examine the motivating factors for ad-hoc networks and sensor networks.The motivating factors for cross-layer design for ad hoc networks include:

- Cross-Layer Aspects: Nodes in wireless ad hoc networks [41],[42] have to manage several performance aspects like system management, power management, and security management that cut across traditional layers. For example, both medium access and routing decisions have significant impact on power consumption, and the joint consideration of both can yield more efficient power consumption thereby increasing the battery life. The strict boundary separation of layers in the layered architecture and standard interlayer interfaces in traditional approaches do not permit adequate communication among layers to make joint decisions to optimize these cross-layer aspects. This has led to the proposal of new interaction models to support cross-layering, ranging from a more relaxed information flow and sharing between layers to full-fledged merging of layer functionalities.

- Distributed State: In the traditional infrastructure models the base stations has a global view of the network state, where as in contrast with the traditional view, the network state in ad hoc networks is generally distributed across the nodes. Each node forms its own local view of state, representing a partial view of the overall network state. In most of the cases, it is not feasible to collect network state at any one of the node, which prevents the use of any centralized optimization algorithms [38]. As such, each node can run distributed algorithms locally using its partial view of network state. Distributed algorithms can exploit a cross-layer design to enable each node to perform fine-grained optimizations locally whenever it detects changes in network state.

- Mobility: Mobility introduces an additional challenge for ad hoc network design. Routing protocols would have to cope with this mobility of the mobile terminals by constantly adapting routing state to the changing user positions. Let us now consider mobility in the context of ad hoc networks, where no node has global view of network state. Mobility management poses an added challenge to the battery-powered nodes in ad hoc networks, which have to adjust their behaviour to the changing node locations. Mobility causes changes for the physical layer (for e.g. interference levels), the data link layer (for e.g. link schedules), the routing layer (for e.g. new neighbouring nodes), and the transport layer (for e.g. connection timeouts). As such, a cross-layer based design enhances the capability of the node to manage its resources in the mobile environments [39].

- Wireless Link Properties: Wireless links are more susceptible as compared to the wired links to interference variations and channel errors [40]. For instance, in the example of the TCP congestion control problem [37] over wireless links, in which TCP misinterprets a packet loss due to channel error as a sign of congestion. Wireless links are also more vulnerable to security attacks because of easy access to the wireless channel as the wireless channel is open. If the wireless link status information is provided at the higher layers the nodes can adapt their configuration in a better way at the physical layer. For example, a routing protocol detects degradation in the signal strength of a particular wireless link then it can divert the traffic to another wireless link which has an adequate quality on the link.

- New Communication Modalities: Ad hoc network design can exploit the broadcast nature of the channel to enhance performance. For example, nodes can sneak on the neighbouring transmissions in order to estimate and evaluate the quality of links with neighbours. Antenna arrays can also enable the reception of multiple packets simultaneously on the wireless channel and the data packets corresponding to several connections could also arrive simultaneously at a node. The cooperation of various layers such as routing, data link, and physical layer can ensure the forwarding of data for all the connections within time.

- Inherent Layer Dependencies: in a layered protocol stack there exist a number of interlayer dependencies which motivate cross-layer design for ad hoc and sensor networks. The data link and routing layers in ad hoc networks exhibit both variable interaction as well as algorithmic interaction, telling the need for design through coupling of these layers. The data link layer is also closely related with the physical layer. The physical layer deals with the channel state and the data link layer with the error control and flow control. If the change in the channel state at the physical layer is provided to the data link layer then it can adapt error control mechanisms in a adaptive manner, thereby improving the throughput.

- Security: due to the fact that a wireless channel is open and could be access easily by an attacker security has become more and more important to secure our communication. Security is an important concern in wireless networks due to their increased vulnerability and exposure to varying types of attacks. Unreliable wireless links, frequently changing network topology and lack of a centralized system to handle the security needs of the network contribute to insecure standalone systems in wireless networks. Intrusion detection systems located on concentrated points such as network gateways and wireless access points are not guaranteed to achieve the desired security level in the network [10],[11],[12]. There exists a need of an efficient and reliable intrusion detection system to manage the access control and provide a monitoring unit to detect any anomalous behaviour in the network [43],[44],[45]. In a wireless network protocol stack, every layer is vulnerable to attacks (internal and external) by adverse nodes in the network. Independent security solutions at different layers might lead to conflicting actions and result in performance degradation. Hence, ensuring security and network reliability, has to be jointly addressed in all of the protocol layers. Proper interaction and coordination among different protocol layers helps in developing a robust intrusion detection system suitable for wireless networks. Such interactions are the key elements to building cross-layer architectures. Apart from the need to make a collaborative decision, adopting a cross-layer approach to intrusion detection facilitates effective fault diagnosis and reduced false alarms. Physical layer authentication for the detection of the intruder when integrated with the cross-layer design can improve the security of the wireless networks [46], [47].

- Resource-Constrained Nodes: The mobile nodes for ad hoc networks are decreasing in size, which results in the use of smaller batteries for these nodes. Cross-layer design approaches can expose power related variables at several layers, enabling nodes to efficiently utilize their energy resources and to maximize the battery life of the node.

Cross-layer design offers performance benefits for a particular system, yielding short-term gains [36]. In contrast, the architecture offers a model for sustained innovation in a system, so it offers long-term gains. Yet many ad hoc and sensor network applications are quite specific in nature, so the short-term performance gains of cross-layer design may be more significant for the network user to make efficient use of limited node resources. Wireless channels have limited frequency allocations and channel considerations, which distinguishes it with the wire-line counterpart. In many literatures, the motivating factor of the cross layer design in the wireless channel is the wireless channel itself. The characteristics of the wireless channel are not constant over time. Following are the factors which raises the need for the cross-layer design in wireless networks:

a). The response of the wireless channel varies over time and space and has short-term fading due to multipath. These variations can be caused due to either motion of the wireless device or changes in the surrounding physical environment, and lead to errors at the receiving end [48]. This causes bursts of errors to occur during which packets cannot be successfully transmitted on the link. Small-scale channel variations due to fading are such that the channel response of different channels can switch from “good” to “bad” within a few milliseconds and vice versa. Furthermore, if very strong forward error correction codes (very low rates) are employed to eliminate the burst errors then it reduces the spectral efficiency.

b). In addition to small-scale channel variations, there are also spatial and temporal variations on a much greater timescale [49]. Large-scale channel variation means that the average channel response depends on user locations and the level of interference on the channel. Thus, due to small-scale and large-scale channel variations, some users may essentially demand more channel access time than others based on their location and/or mobile velocity, even if their data rate requirement is the same as or less than other users. The improvement in the channel characteristics can be improved if the strict physical and MAC layer boundaries can be made soft i.e. by the use of the cross layer design concepts.

2.3. Cross-Layer Proposals

While reviewing various works by the researchers, we came across a large number of cross-layer designs proposals. A classification of such proposals are based on the layers that are coupled by the different proposals can be found in [50]. This section gives a classification of the existing cross-layer design proposals according to the type of architectural violations they represent in the design. We assume here that the reference architecture has the application layer, the transport layer, the network layer, the link layer which comprises the data-link control (DLC) and medium access control (MAC) sub-layers and the physical layer with all the layers performing their generally understood functionalities. The following are the architectural violations which are proposed by various literatures:

1) Designing new interfaces as shown in Fig. 3(a, b, c, d)
2) Merging of adjacent layers as shown in Fig. 3(e).
3) Vertical calibration across layers as shown in Fig. 3(f).

Many of the cross-layer designs proposals require creation of new interfaces between the layers preferably non-adjacent layers. These can further be divided into three categories depending on the direction of information flow along the new interfaces:

a) Upwards: From lower layer(s) to a higher-layer.
b) Downwards: From higher layer(s) to a lower-layer.
c) Back and forth: Iterative flow between the higher and lower layer.

1) Designing New Interfaces: In this new interfaces between non adjacent layers are developed. These are designed into three subcategories; we now discuss the three sub-categories in more detail.

a) Upward information flow: A higher layer protocol that requires some information from the lower layer(s) at runtime results in the creation of a new interface from the lower layer(s) to the higher layer, as shown in Fig. 3(a).

For example, Rappaport in [51] discussed the end-to-end Transmission Control Protocol (TCP) over a wireless link. TCP is a connection-oriented, end-to-end data transfer protocol. It performs reliable end-to-end transmission of data that is achieved by error detection and re-transmission of the packet and congestion control over the Internet. The routers deployed in the network drops the packets when there is congestion in the network which in turn tells the sender node to adaptively decrease the sending packet rate. The TCP is expected to include the Explicit Congestion Notification (ECN) mechanism which is responsible to notify the receiver whenever congestion errors occurs on the wireless link and can trick the TCP sender making erroneous inferences about the congestion in the network and as a result, the performance deteriorates. Creating interfaces from the lower layers to the transport layer to enable explicit notifications can eliminate such situations. For doing so we have to violate the layered protocol stack in which there exists no interface between the lower layer and the transport layer directly hence it is a cross layer proposal with the help of which network performance in terms of throughput can be increased in a TCP based network.

b) Downward information flow: Some proposals of the cross-layer design depends upon the parameter setting on the lower layer of the protocol stack at run-time using a direct interface from some higher layer, as figured in the Fig. 3(b).Such an example of the downward flow of information is termed as a hints in the literature given by the author in [52]. As an example, the applications can inform the link layer about their delay requirement, and the link layer can then treat packets from the delay sensitive applications with priority [53].

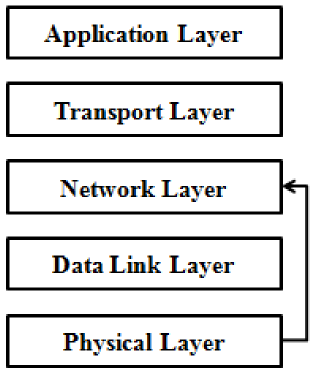

Fig. 3(a)

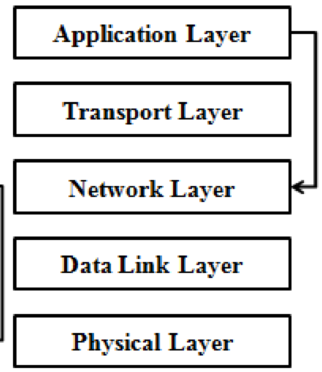

Fig. 3(b)

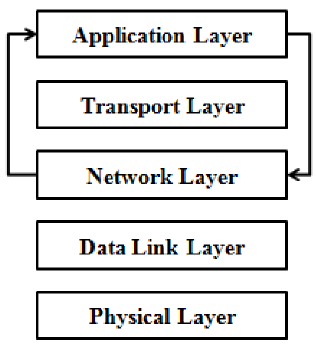

Fig. 3(c)

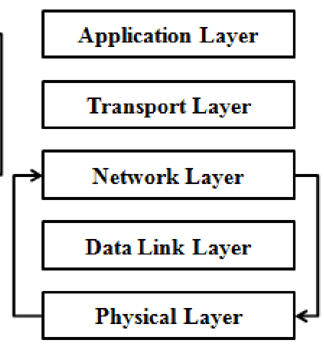

Fig. 3(d)

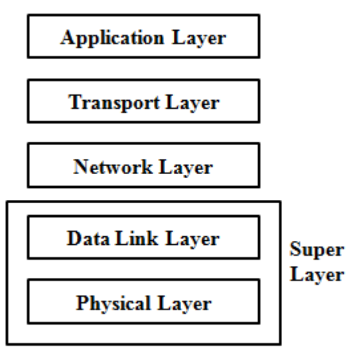

Fig. 3(e)

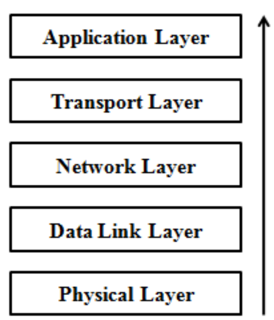

Fig. 3(f)

Fig.3. Different Cross-Layer Proposals

c) Back and forth information flow: Any two layers which performs different tasks can communicate with each other at run-time. Very often it manifests in an open loop between the layers which is iterative in nature and provides the information flow back-and-forth between layers such as in Fig. 3(c) and Fig. 3 (d). The author of [54] discussed a collaboration between the MAC and the physical (PHY) layers in the uplink of a wireless LAN system, as in the Network-assisted diversity multiple access (NDMA) proposal. Conventionally, the resolution of collision is done exclusively at the MAC layer. With more sophisticated signal processing, the PHY layer becomes capable of recovering packets from collisions, and hence can collaborate with the MAC layer. This is the idea which is discussed in the NDMA proposal [54]. Principally, when a collision is detected, the base station estimates the number of user that has collided and then it request for retransmission from the user which have collided so as to recover the message again at the receiving end.

2) Merging of adjacent layers: Two or more adjacent layers of the protocol stack can be designed or merge together such that the service provided by the new layer which is the “super-layer” is the combination of their respective services which are supposed to provide by the individual layers as illustrated in Fig. 3(e). This adds substantial complexity in the protocol design as this super-layer has to be interfaced with the remaining layers of the protocol stack which exists in the original architecture. Although we have not come across any cross-layer design proposal that explicitly creates a super-layer but to some extent the collaborative design between the PHY and the MAC layers discussed in NDMA proposal is an idea which tries to trace- pass the restricted boundary between these two adjacent layers.

3) Vertical calibration across layers: This type of the cross-layer design proposals refers to adjusting parameters that extend across the layers of the protocol stack, as illustrated in Fig.3(f).The advantage of such a design is very easy to understand. The overall-performance of a layer is seen at the level of the application is a function of all the parameters at all the layers which are below it. It is feasible that a collective action can help to achieve better performance than that of the performance of network in which the parameter are set at the individual layer (in case of the protocol designed in the traditional layered format where protocols are designed at individual layers independently). As an example let us consider the proposal of the author presented in [55] in which for optimizing the throughput performance of the Transmission Control Protocol (TCP), the author collectively takes tuning power management, Forward Error Correction (FEC) and Automatic Repeat Request (ARQ) settings. In [56] author developed a cross-layer design which combines adaptive modulation technique and coding at the physical layer with a truncated automatic repeat request protocol (ARQ) at the data link layer, in order to maximize the spectral efficiency under prescribed delay and error performance constraints. It is an example of vertical calibration where the delay requirement dictates the persistence of the link-layer ARQ, which in turn becomes an input for the deciding the rate-selection through a channel-adaptive modulation scheme. Vertical calibration can be done in a static manner, which involves setting parameters across the layers at design time with the optimization of some metric so as to give better performance of the scenario in mind. On the other hand it can also be done dynamically at run-time, which emulates a flexible protocol stack that responds to the variations in the channel, traffic and overall network conditions. Static vertical calibration does not create significant consideration for implementations since the parameters can be adjusted once at design-time and left untouched thereafter. Dynamic vertical calibration, alternatively, requires mechanisms to retrieve and update the values of the parameters being optimized from the different layers. This may invite significant cost in terms of overheads in terms of time and complexity and also impose strict requirements on the parameter retrieval and their update process to make sure that the knowledge of state of the stack is recent and exact.

3. EVALUATING A CROSS-LAYER PROPOSAL

If we talk about the standardization of the cross layer proposals, across the seven layers of the OSI stack, researchers have proposed many cross-layer optimizations. Any Cross-layer design proposals falls into two categories as per as the application requirement is concerns which are as follows:

- Optimization objectives
- System constraints.

An optimization objective might be network lifetime which is defined as the length of time for which a network maintains its application-specified functionality. In general, the constraints are either constructive or destructive. We define constructive constraints as those which provide relaxations such that the system can provide more optimization gain. Destructive constraints have the opposite characteristic, whereby they cause the system to have lesser optimization gain. In evaluating each CLD proposal, it is suggested [57] to consider the following criterion:

1) Define the layers which are involved in the proposal
2) Check the system-model and the assumptions invoked
3) Mention clearly the Optimization Objectives
4) State the system constraints, constructive and destructive
5) Explain the nature of the optimization
6) Define new requirements for each involved layer

4. CHALLENGES INVOLVED IN CROSS-LAYER DESIGN

In the previous section we have discussed the ongoing works in the field of cross-layer design and this section we will be discussing the challenges offered by the architecture to the researchers. For pointing out the challenges in this section, we came across various design proposals given in the literature and found some initial ideas on how cross-layer interaction can be implemented. The following are the challenges:

- How to identify the most important cross-layer design technique which best fit for our model?
- How to achieve better network performance?
- Have we made the cross-layer proposal after a detailed study keeping in mind all the effects of the layer-interaction on the parameters of different layers and on the overall network?
- Which layers of the protocol stack should be involved in the cross-layer proposal?
- Whether we should go for the deployment of new interfaces bypassing the adjacent layers or for merging of layers?
- How these non-adjacent layers will communicate with each other?
- What information should be exchanged across protocol layers and how frequently this information exchange should take place?
- What are the adequate / efficient procedures to exchange this information?
- How to counter the loss of the respective header which will be lost when direct communication takes place between the non-adjacent layers?
- What is the trade-off between the improved network performance and the loss of modularity?

- For what network and environmental condition would a particular cross-layer proposal be invoked?
- Can we able to make a standard interface which is responsible for the information sharing between the cross-layers?
- Is there any possibility to involve two cross-layer technologies working simultaneously?
- How to make a cross layer proposal secure? Can a cross-layer framework designed for optimizing network security be coupled with other cross-layer based network optimizations?
- What role is assigned to the physical layer? Physical Layer plays a very important role in the designing of a wireless network. Advanced signal processing at the physical layer provides valuable functions such as subcarrier allocation, rate adaptation, and channel-aware scheduling. The inherent variability of the wireless medium may impact the function of network layer protocols, thus affecting end-to-end performance. The cross-layer design mainly relies on the unique features of the physical layer to achieve better quality of service (QoS) over the multi-cell wireless networks such as the case of the OFDM and CDMA.
- How to determine a common platform to implement cross-layer design proposals and study their performances using simulations? Current network simulators such as QUALNET, OPNET, NCTUNS, NS-2, J-Sim, and GloMoSim may be unsuitable to implement a cross-layer solution, since their inner structure is based on a layered architecture, and each of the implemented functionality run by the simulator engine is tightly tied to this architecture. Therefore, implementing a cross-layer solution in one of these simulators may turn into a non-trivial task. For this reason, there is a requirement to develop new software simulators that are based on a new developing paradigm known as cross-layer design, to make the development and testing of the cross-layer based proposal unproblematic.

5. CONCLUSIONS

Researchers always do work for the betterment of the society. While doing so, there is always a tendency, and in fact a need, to optimize performance in any system. This generally creates trade-off between performance and architecture. In the case of wireless networks, we can see this tension/trade-off when we talk about the cross-layer design. In the cross-layer design the architecture is updated or modified and it requires complete redesign and replacements. The cross-layer design creates interactions, some intended, and others unintended. We must study the dependency relations and the consequences of all such interactions and try to develop some mathematical proofs in the form of theorems. In this paper we have reviewed the literature available on cross-layer design, and classified the literature on various aspects like definition, motivation, various cross layer proposals and their categories, evaluating factor and various open challenges in this domain. We have given the open research issues which will be helpful for the people who want to do research in this area. Cross-layer design can be implemented for network security. When the channel is wireless then authentication of the wireless terminal is a serious issue which can be solved by proper authentication of the wireless terminal. Physical layer authentication in which the channel probing or channel estimation is used when integrated with the cross-layer design can enhance the security of the network [43-47].

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