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Cross Layer Design and Energy Efficient Protocol for Wireless Sensor Network

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ABSTRACT
The Open System Interconnection (OSI) layered protocol model divides networking tasks into layers and defines a set of services for each layer to be provided individually. The design of the protocol makes the services realized for different layers, no direct Communication between nonadjacent layers is permitted as the architecture forbids such an action, also communication is limited to procedure calls and responses between adjacent layers. Whereas the cross layer design violates the reference architecture, by allowing direct communication between protocols at non adjacent layers. It also allows sharing variables between layers, which gives it a better performance in the area of wireless communication. In order to support better usage of wireless users the cross layer design paradigm has been proposed. This paper covers definition, proposed designs, evaluation, challenges and research issues of cross-layer design.

Keywords: *cross-layer design, optimization, gain*

I. INTRODUCTION

The OSI standard has led to efficient protocol design because of the strict and clear boundaries between the layers. Each layer makes no assumptions about the adjacent layers, other than that they will be capable of pre-defined interactions as specified by the OSI standard that means lower layers provides services to the above layer. Thus, a single layer can be upgraded or replaced without affecting the design of the other layers.

Over the last three decades, this approach has been shown to produce modular, robust and enduring communication system. In [2], the authors present historical examples of well-defined architecture which have led to long-term success for a number of different designs.

Wireless communications and networking occupy center stage in research and development activity in the area of communication networks. Recent research has shown that the OSI model is not necessarily the correct approach for some modalities of wireless communication. Researchers have made some modification to communication protocols which violets the OSI model, but achieves specific optimization goals. These modifications are termed as "cross layer design (CLD)" [1].Thus, there are number of cross-layer design proposals in the literature. The main motivation for cross layer design is human mentality and psychology. 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.

Cross layer design is described in different ways. They are:

"Cross-layer design refers to protocol design done by actively exploiting the dependence between protocol layers to obtain performance gains", "Violation of a layered architecture is cross-layer design with respect to the reference architecture", "The core idea is to maintain the functionalities associated to the original layers but to allow coordination, interaction and joint optimization of protocols crossing different layers", "Cross-layer design is defined as a protocol design methodology. However, a protocol design with this methodology is also termed as a cross-layer design"

II. CROSS LAYER DESIGN PROPOSALS

While reviewing various works by the researchers, we came across a large number of Cross-Layer Design Proposals based on the published research articles. 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 onthe direction of information flow along with the new interfaces:

1. Upward Information Flow

It is a scheme which proposes the idea of having direct access between two layers where the flow of the information comes from the lower layer to the higher layer. This scheme proposes that one higher layer is exposed to the lower layer requests which are forbidden by the architecture.

The formation of another interface from the lower layer to the higher layer at runtime is an outcome, when higher-layer requires data from the lower-layer(s), as appeared in figure 1. Making interfaces from the lower layers to the higher layer to empower unequivocal notices. Upward data stream fills the need of informing the higher layers about the hidden network conditions.

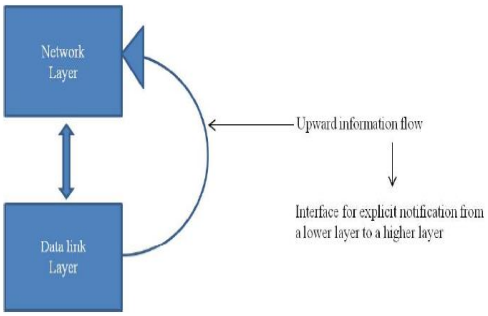

Figure 1: upward movement of data

2. Downward Information Flow

Some Cross layer design recommendations depend on setting parameters on the lower layer of the stack at runtime utilizing an immediate interface from some higher layer, as delineated in figure 2. A decent approach to take a gander at the upward and downward information flow is to regard them as warnings and insights individually. Downward information flow is intended to give indications to the lower layers about how the application information ought to be handled. This plan additionally proposes the restricted information head out from higher layer to lower layer of two or more layers that are not permitted to impart to each other straight forwardly. The stream of data driven from higher layer to the lower layer makes another interface and administrations among them to maintain a strategic distance from the general method for operating in the stack.

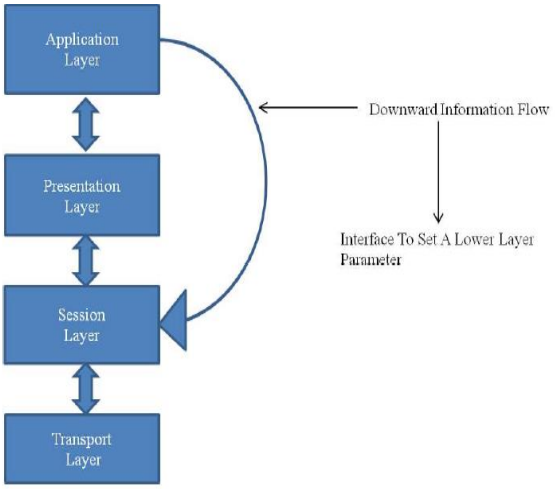

Figure 2: Downward movement of data

3. Back and Forth Information Flows

Two layers, performing different tasks, can collaborate with each other at runtime. The architecture here is violated by the two complimentary new interfaces. The repeated loop between the two layers with information flowing back and forth is clearly shown in the figure 3. Basically, with improvements in the signal processing at the physical layer, it becomes capable of

recovering packets from collisions. This scheme is concentrating with more than one layer to optimize at run time. It proposes the idea of having two nonadjacent layers working with each other simultaneously. Such scheme intends to provide corporative relation between multiple layers so if one layer is sending notifications to another layer it could also receive notification fromt he other layer(s). Similarly it is a parallel system where interaction between two layers is possible at both ways up and down in the stack.

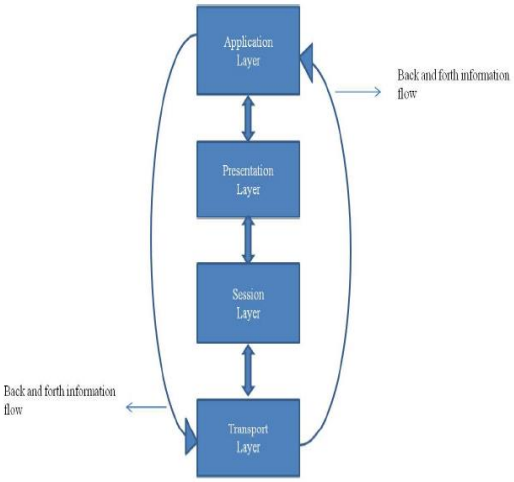

Figure 3: Back and forth information flow

4. Merging of Adjacent Layers

It is a design of two or more adjacent layers that work as new super layer with a union of service provided by the constituent layer. This does not require any new interfaces to be created in the stack. Architecturally speaking, the super layer can be interfaced with the rest of the stack using the interfaces that already exist in the original architect. The idea presented is about getting two layers working as one layer, in other words having all the services provided by these layers interacted and acting like one super layer. Of course such scheme requires rebuilding of the services in the selected layers but if such merging happened to be achievable than data transfer would become faster, because of the fact that we will not do any changes to either interface or services in all the stack of the OSI as it will be exclusively in the selected two layers. Figure 4 illustrates the working of super layer.

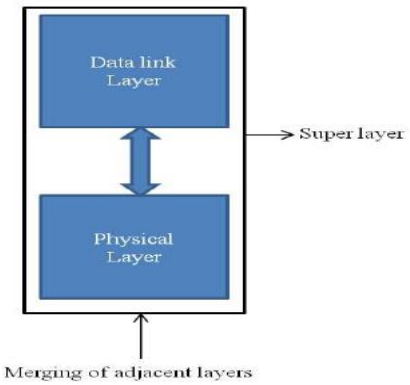

Figure 4: Merging of adjacent layers

Cross layer design based on interactions can be implemented arealsobeing made in the literature. These can be putinto three categories:

i) Direct communication between layers.

A straightforward way to allow run-time information sharing between the layers is toallow them to communicate with each other.

ii) A shared database across the layers.

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The other class of ideas propose using a common database that can be accessed by all thelayers, [3].In onesense, the common database is like a new layer, providing the service of storage/retrievalof information to all the layers.

iii) Completely new abstractions.

This approach which presents a new way to organize the protocols in heaps and not in stacks as done by layering [4].Such novel organizations of protocols are appealing as they allow rich interactions between the building blocks of the protocols as shown in figure 5. Hence, potentially they offer great flexibility, both during the design as well as at run-time.

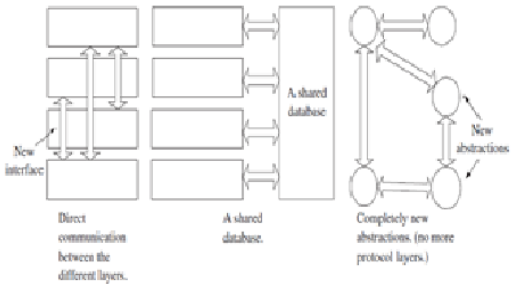

Figure 5: Proposal for architectural Blue Print

III. EVALUATING A CROSS–LAYER PROPOSAL

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: An optimization objective might be network lifetime which is defined as the length of time for which a network maintains its application-specified functionality.

***System constraints*:** 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 havethe opposite characteristic, whereby they cause the system to have lesser optimization gain.

In evaluating each CLD proposal, it is suggested [5] to consider the following criterion:

Define the layers which are involved in the proposal

- Check the system-model and the assumptions invoked
- Mention clearly the Optimization Objectives
- State the constructive and destructive system constraints
- Explain the nature of the optimization
- Define new requirements for each involved layer

IV. CHALLENGES IN CROSS-LAYER DESIGN

Cross-layer design has some challenges [7] that are summarized as follows:

- The lack of standard framework for Cross-layer design.
- It is not clearly specified when, where and how different Cross-layer design proposals should be implemented.
- How 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 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?

V. RESEARCH ISSUES IN CROSS-LAYER DESIGN

Some of the research issues dealt with the help of Cross layer designs are [6]:

- Application layer adaptation based on cross layer strategies.
- Cross layer design framework for real-time multimedia streaming.
- Cross layer content delivery architecture.
- Complexity and scalability issues in cross layer design.
- Signaling for cross layer protocol interaction.
- Scheduling Algorithms and Link Adaptation.
- Interactions among PHY/MAC/RLC and transport layer protocol.
- Cross layer adaptation for energy minimization in wireless networks.
- MAC protocols with multimedia QoS support in wireless networks.
- Transport/streaming protocols for end-to-end QoS support.
- Applications of network coding in cross layer design.
- Protocols' implementation, analysis of correctness and efficiency, and Interoperability with legacy system.
- Energy saving and power control protocols for ad hoc and sensor networks.
- Cross-layer strategies in 2G/3G/4G cellular system, wireless sensor, ad hoc Networks and other emerging communications.
- Cross-layer design and implementation in Software defined and cognitive radio.

VI. CONCLUSION

This article has attempted to provide an over view of the Cross-layer design as a suitable technology to overcome some of the current limitations of OSI model stack, especially in the case of wireless networks. Its core idea is to maintain the functionalities associated to the original layers but to allow coordination, interaction and joint optimization of protocols crossing different layers. The relevance of cross-layer design is clear in today's and tomorrow's wireless networks. However, even though thousands of contributions are available on the research topic on cross-layering is still opening new perspectives, especially on architectural issues and dynamic adaptation of network behavior. But also on the tradeoff between performance and inter operability,a Cross layer design is believed to be a promising future in the sense of the daterate transfer and effective design, which can solve the increase of wavelength datarate. Normal architecture can also be used at all-time but if the requirements have become heavier in future as a video calling, online games and more applications are now used for communication and entertainment, eventually these applications require faster data transfer rate to achieve the maximum possible throughput. Despite the fact that developing new rules in the existing architecture is not an easy task, but the need for better network capacity requires developing the Cross layer Design.

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