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CROSS LAYER DESIGN FOR WIRELESS LOCAL AREA NETWORKS (802.11)

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Abstract: Wireless local area Networks (WLAN) have grown to become a really engaging answer to supply network connectivity, providing user quality, flexibility and simple deployment at a comparatively low cost. The recognition and, therefore, the traffic load of WLANs grows furthermore because the necessity to support real-time delay-sensitive applications like voice, video streaming or online gaming. Therefore, the requirement for higher efficiency and Quality of Service (QoS) guarantees becomes necessary. With the speedy development in wireless communication technologies, the IEEE 802.11 WLANs are experiencing a huge acclaim and widespread deployment. Designed with ancient layered design, current WLANs adopt functional layer division and aim at optimization at individual layers. However, in a highly dynamic and media sharing wireless atmosphere, the capability enhancements at individual physical layers might not essentially profit, and typically even deteriorate the system performance with multiple users. It has been proved that the consideration of the physical layer transmission characteristics from the upper layers will considerably improve the efficiency of the wireless local area network systems. In general, the exchange of data between completely different layers of the OSI model is thought as Cross-Layer design and could be a very promising field of investigation and deployment. Hence, the cross-layer design is described here with regard to 802.11 WLAN.

Keywords: Cross Layer Design, DCF, IEEE802.11, WLAN.

I. INTRODUCTION

With the widespread of mobile devices like smartphones and tablets, wireless technology is quickly changing the strategy of alternative for network access [8]. One in all these wireless technologies, IEEE 802.11, ordinarily called WLAN, is widely adopted in indoor environments like enterprises, organizations, and homes. It is conjointly a quick and cheap alternative to cellular networks for internet access. Nowadays

WLAN is present nearly all over, because the most diverse electronic devices, from mobile phones to home appliances, go along with integrated WLAN chipsets. Users will connect effortlessly as a result of WLAN provides a straightforward setup and configuration. Since its introduction, over fifteen years past, the uses and capabilities of IEEE 802.11 Wireless local area Networks (WLANs) have evolved significantly:

- Originally Wi-Fi was seen as a replacement for wired links. Moveable computers connected wirelessly, however from fixed locations. Lately, mobile devices, mainly handsets that consume each voice and internet services, demand on-the-go connectivity.
- First data bit rates ranged from one to a pair of Mb/s, however, Wi-Fi can currently bring home the high speeds of up to 1.3 Gb/s.
- Initially designed for the best-effort track, Wi-Fi later incorporated quality of service mechanisms to support multimedia system applications with tight constraints.
- The original Wi-Fi security algorithm suffered many flaws and was finally deprecated. Strong authentication and traffic encoding algorithms were after introduced.

A stratified design, just like the seven-layer open systems interconnect (OSI) model, divides the networking task into layers and defines an order of services to be provided by the individual layers [9]. The services at the layers are accomplished by coming up with protocols for the various layers. The design forbids direct communication between non-adjacent layers; imparting between adjacent layers is restricted

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to procedure calls and responses. It is repeatedly argued that though stratified architectures have served well for wired networks, they are not appropriate for wireless networks. The complexness and time-varying attributes of the wireless channel demand cross-layer design. Protocols may be designed by violating the reference design, for instance, by permitting direct communication between protocols at distant layers or sharing variables between layers. Such violation of a stratified design is named cross-layer design with reference to the reference design. Therefore, considering of these aspects, we discuss here the cross-layer design for wireless local area network.

II. REVIEW OF RELATED WORK

The related work is discussed below.

Reference [10] proposes a cross-layer design for the IEEE 802.11 WLANs, "Weighted fair scheduling supported adaptive Rate Control" (WFS-ARC), for joint rate administration and packet scheduling, so the LLC/MAC layers will exploit the multi-rate PHY layer capability and, therefore, the multiuser diversity. The problem is modelled to maximize the system good put with a rate adaptive MAC layer whereas satisfying the allotted fairness constraints. The saturation behavior in numerous cases is studied and therefore, the simulation results demonstrate that through the elegant cooperation of various layers, the superior performance gain are often achieved. This theme is often simply adopted by the state-of-the-art IEEE 802.11 AP (Access Point) products since it is often enforced within the device driver and no modification to the hardware or the standard is needed. It ought to even be straightforward to increase this framework to ad hoc networks.

A prime technology in cooperative communications is distributed space-time coding (DSTC) that achieves spatial diversity gain from multiple relays. A unique DSTC, known as randomized distributed space-time coding (R-DSTC), shows appreciable advantages over an everyday DSTC in terms of system complexness. Reference [11] exploits the advantages of R-DSTC physical (PHY) layer and develops a distributed and opportunistic medium access control (MAC) layer protocol for R-DSTC deployment in an IEEE 802.11 wireless local area network (WLAN). In contrast to alternative cooperative MAC designs, within the proposed PHY-MAC cross-layer framework, there is no need to decide that stations can function relays before every packet transmission. Instead, the MAC layer opportunistically recruits relay stations on the fly; any station that receives a packet from the source properly forwards it to the destination. Through in-depth simulations, the efficiency of their MAC layer protocol is validated and it is demonstrated that network capability and delay performance is significantly improved with relation to legacy IEEE 802.11g network.

All the nodes within the mobile ad-hoc network (MANET) cooperatively maintain the network connectivity. Exploiting the dependencies and intercommunication between layers has been shown to extend performance in certain situations of wireless networking. Though stratified constructions have served well for wired networks, they are not appropriate for wireless networks. The wireless network has many benefits over the wired technologies like flexibility, mobility, cheaper and quicker deployment, easier maintenance and upgrade procedures. These issues move to cross-layer design (CLD). However, several technical problems still exist in this field; reference [12] presents an in-depth investigation of CLD and challenges, potential complications attached it and simulators. Additionally, the reference briefs the readers a summary of cross-layer conception whereas discussing completely different cross-layer proposals given by researchers, with an objective to sparkle new research interests in this field.

Since battery technology has not progressed as speedily as semiconductor technology, power efficiency has become progressively vital in wireless networking, additionally to the normal quality and performance measures, like bandwidth, throughput, and fairness. Energy-efficient design needs a cross-layer approach as power consumption is full of all aspects of system design, starting from semiconductor to applications. Reference [13] presents a comprehensive summary of recent advances in cross-layer architecture for energy-efficient wireless communications. The analysis paper notably specializes in system-based approaches towards energy optimal transmission and resource management across time, frequency, and spatial domains. Details associated with energy-efficient hardware implementations also are covered.

Currently the IEEE 802.11 is that the de facto standard for wireless local area networks (WLAN). It specifies each the medium access management (MAC) and, therefore, the physical (PHY) layers for WLANs. Concerning to cross-layer mechanisms and flexible communications over WLANs, there are several new and important challenges with regard to wired and traditional wireless networks. In fact, as presently as to optimize data transmission in keeping with each the characteristics of the data and to the varied channel conditions, a cross-layering approach becomes necessary. The thesis [14] proposes efficient flexible transmission mechanisms using cross-layer interactions in WLANs.

III. CROSS LAYER DESIGN METHODS FOR WIRELESS LOCAL AREA NETWORK

Considering the importance of cross layer design for wireless local area network some of the techniques are discussed below.

Reference [1] proposes a cross-layer design (CLD) framework for improving the performance of wireless local area network (WLAN). It is known as channel aware buffer unit multiple accesses (C-BUMA). Within the framework physical layer is combined with medium access control layer for packet transmissions. It is demonstrated that CLD will considerably improve network throughput and packet delay. The projected C-BUMA is straightforward and might simply be enforced in 802.11 networks while not ever-changing hardware infrastructure and no additional costs. The C-BUMA algorithm is presented and 2 algorithms are given for the implementation of the framework.

In the framework, radio propagation modelling of the physical layer and MAC protocol are integrated into one single layer. The propagation modelling anticipates the wireless channel state and shares the channel state information (CSI) with the MAC protocol. Having access to the CSI before sending a packet, the MAC protocol will estimate whether or not the channel is "good" enough to ensure a successful transmission. The receiving station determines channel status by crucial received signal's bit error rate. The wireless channel is classed on the premise of bit error rate (BER).

The algorithm 1(wireless channel prediction) works as follows;

- if the BER < 10^{-6} the channel state is taken into account as good.
- if the BER < 10^{-3} the channel state is taken into account as bad.
- otherwise, the channel state is taken into account as very bad.

The planned channel prediction algorithmic rule is easy and doesn't need in-depth computation. Thus, it is simple to implement in real systems.

The algorithm 2(Transmission Control) works as follows:

- get CSI from channel prediction algorithm;
- get network traffic information;
- if the channel state is good_BER then buffer length is formed to 3;
- slot status is BUSY and multiple packets are transmitted;
- else if channel state is bad_BER then buffer length is formed to 1;
- slot status is BUSY and one packet is transmitted;
- else packet transmissions are paused;
- wait for successive empty slot;
- end.

The algorithmic rule prevents the sender from inessential transmissions that result into a reduction in power consumption. It saves transmission bandwidth that may be used for sending payload and achieves higher throughput. The algorithmic rule is enforced simply while not ever-changing existing DCF hardware.

The performance of the projected CLD framework is evaluated by ns-2.31 simulations. The ns-2 simulation model was validated through real measurements using 802.11b wireless cards. Additionally, ns-2 results were compared with the results obtained from OPNET modeler and a decent match between 2 sets of results additionally validates the simulation models.

The framework relies on C-BUMA, a channel aware MAC protocol. The projected CLD combines the radio propagation and also the MAC layer into one layer. By sharing channel information with the MAC protocol, the approach lowered unnecessary packet transmissions, and so considerably improved system performance. Simulation results show that the network achieves 13.5% higher throughput and 56 % lower packet delay with CLD.

Reference [2] proposes cooperative MAC protocol to maximize the benefit of cooperative diversity. It enhances IEEE 802.11 DCF with minimum modifications. The reference also proposes cluster based cooperative routing protocol which has minimum control overhead and time consumed in establishing cooperative paths.

In this technique, high rate stations assist low rate stations in their transmissions by forwarding their traffic. The helper with the most effective two-hop transmission rate, that has a minimum delay for information transmission from source to helper and from helper to the destination, is taken into account because the best helper is chosen as a neighbor node for that specific source-destination combine. It is assumed that the location information of the nodes is notable so the Euclidean distance between each pair of nodes may be computed. Since the data rate of a link is related to the distance between the nodes, the computed distances will be simply converted to the corresponding information rates. Each node within the network maintains a cooperative table (CT) of potential helpers, that contains the MAC address of all destinations that may be reached through one-hop transmission, the direct Euclidean distance to the destination, the MAC address of the helper (if a helper is present), and also the total distance through the helper. If no helper is available, the helper address is same the destination address. It is backward compatible with legacy 802.11 DCF and has a negligible modification to the data frame (MAC Protocol data unit) header and also the RTS-CTS management frames. A straightforward example network is shown in Fig. 1.

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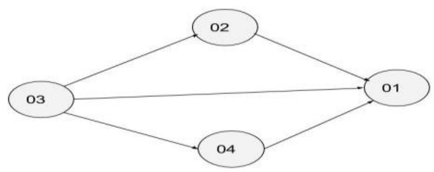

Figure 1: Helper selection in M-CMAC protocol [2]

TABLE 1: COOPERATIVE TABLE AT NODE 3 [2]

MAC Address of destination	Helper Address	Direct Distance	Distance via Helper
1	2	97	70
2	2	37	-
4	4	55	-

Frame Control	Duration	Source Address	Destination Address	Helper Address

Figure 2: RTS Frame Format [2]

A cluster primarily based cooperative routing protocol with multi-hop data forwarding function realized at link layer is proposed. The protocol involves two stages: routing relay choice part and data forwarding part.

Fram e Contr ol	Durati on	Sourc e Addre ss	Destinat ion Address	Addre ss 3	Sequen ce Contro l	Addre ss 4

Figure 3: MAC PDU Header Format [2]

The routing relays are selected independently by every node, primarily based solely on its own relay table. A node is chosen as a relay if it connects the best range of nodes, i.e., the longest row, or it connects nodes that aren't connected by the antecedent selected relay nodes.

If the destination belongs to a distinct cluster, then it searches the relay table to seek out if the destination is often reached through any of the routing relays. If the destination is often reached through any routing relay, the packet is forwarded to the routing relay. The packet is sent to the routing relay via a helper if a helper node exists for this routing relay. Otherwise, it's forwarded on to the routing relay.

The proposed protocols are implemented in NS2 simulator The protocol shows improvement in terms of throughput, delivery ratio, an end to end delay and energy distribution.

In reference [3], a cross-layer predictive channel choice mechanism is proposed to extend utilization and performance in WAVE multi-channel design. It is to be noted that IEEE 802.11p and IEEE 1609.x are collectively referred to as WAVE and specifically IEEE 1609.4 half extends MAC to multi-channel-operations-enable mode.

Federal Communications Commission (FCC) allocates the 5.850–5.925-GHz portion of the spectrum as dedicated short-range communications (DSRC) for transport networks. DSRC customary defines seven 10-MHz channels during this range: one management, 2 reserved, and 4 non-safety application channels as shown in Fig. 4. However, a selection mechanism for these channels is not outlined explicitly.

Frequency (GHz)	SC H	SC H	SC H	CC H	SC H	SC H	SC H
	172	174	176	178	180	182	184
	5.86	5.87	5.88	5.89	5.90	5.91	5.92

SCH: SERVICE CHANNEL, CCH: CONTROL CHANNEL
Figure 4: DSRC Channels [3]

But with the choice theme within the given methodology, channel history is employed to predict the future state of the wireless channel. By making use of the cross-layer design, the MAC layer is fed with energy detector statistics from the PHY layer to create the most effective call to seek out the foremost appropriate non-emergency/service channel. The proposed methodology that is shown in Fig. 5 implies a channel access protocol that improves the effectiveness of collision rejection procedure. The algorithmic rule describes systems and signal model, energy detection, channel choice and results.

Furthermore, the proposed design may well be made user-friendly to varied eventualities and conditions by fittingly choosing the model parameters. The analysis in conjunction with the results shows that the proposed technique outperforms the wide deployed Markov-based prediction method; thus, it is a promising candidate for the WAVE standard.

A link quality based mostly rate adaptation that aims at link throughput optimization has been used wide for IEEE 802.11

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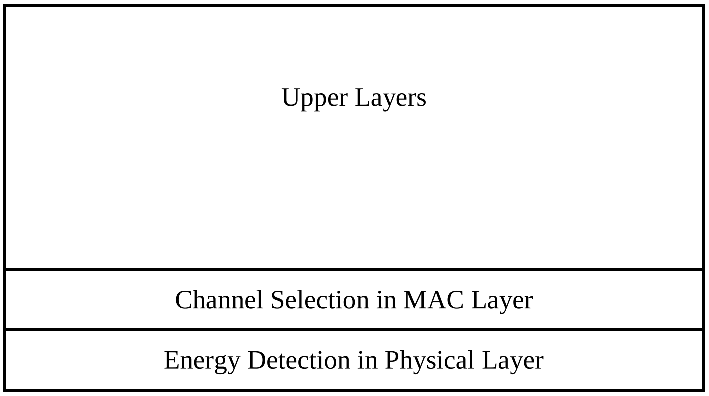

Figure 5: Proposed Cross Layer Architecture [3]

networks. However, from system perspective performance of a network is suffering from not solely from link quality however also from random channel access at the MAC layer. Selection of transmit mode for best link throughput will cause performance loss of MAC throughput.

Reference [4] proposes and investigates a generalized cross-layer SNR (Signal to Noise Ratio) based rate adaptation algorithmic rule MTRA for IEEE 802.11 networks. Each link quality at the PHY layer and channel access competition at the MAC layer are exploited to pick out the most effective transmit mode in terms of best MAC throughput. The cross-layer rate adaptation is completely different from the widely used link adaptation algorithm LTRA that aims to optimize link throughput. Markov chain primarily based analytic model is projected to gauge the performance gains of MTRA algorithm over LTRA algorithmic rule. The impact of channel SNR dynamics, rate adaptation and channel access schemes on MAC throughput are taken into consideration. The results show that cross-layer rate adaptation design in MTRA algorithmic rule will bring appreciable MAC throughput improvement by up to 20%. Through the in-depth investigation on the performance improvement by MTRA algorithm, it is found that the improvement comes mainly from link quality adaptation instead of channel congestion adaptation. Choice of transmit mode by optimizing link throughput in LTRA algorithmic rule may end up in massive performance loss at the MAC layer. And such performance loss cannot be compensated by the means that of optimizing access mechanisms at the MAC layer alone (such as RTS/CTS and adaptive contention window control). So cross-layer design within the MTRA algorithmic rule is sort of effective. They urge that such cross-layer style wants to be exploited in the design of practical rate adaptation algorithms for emerging advanced IEEE 802.11 networks.

Reference [5] presents demo on WiMAC, an all-purpose wireless testbed for researchers to quickly model a good variety of wireless network protocols which are real in time. As the interface between the link layer and also the physical layer, MAC protocols are typically tightly coupled with the underlying physical layer and want to have very tiny latencies. Implementing a brand new MAC needs an extended time. In fact, only a few MACs have ever been implemented, even though dozens of recent MAC protocols are proposed. To enable fast prototyping, the mechanism vs. policy separation is used to decompose the functionality within the MAC layer and also the PHY layer. Engineered on the separation framework, WiMAC achieves the autonomy of the software from the hardware, giving a high degree of function utilize and design flexibility. Hence, the platform not solely supports straightforward cross-layer design however additionally permits protocol changes on the fly.

Modulate and Tx		Timer		Make Packet	PXI-e	Back Off Schedule		Calculate CW
Rx						Timeout and Retry		
		Baseband Control		Packet Buffer				Header and Data
Idle Counter						Channel Assignment		
Switching Channel		Encode and Decode		Throughput		Handshaking		ACK/NACK/BLOCK ACK
Management in FPGA						Policies in Host		

Figure 6: Mechanism vs Policy Separation in WiMAC [5]

It follows the 802.11-like reference design and it is demonstrated that deploying a brand new MAC protocol is fast and easy on the proposed platform The CSMA/CA (Carrier Sense Multiple Access) and CHAIN protocols are implemented. CHAIN [6] is an MAC protocol for enhancing the uplink efficiency.

The necessary features of WiMAC are summarized below:

Independence of software from hardware. In WiMAC, the software-defined policies are detached from the hardware functionality based on the separation framework. Therefore, developers don't seem to be needed to revamp the hardware from scratch since the functional blocks will be reused. The

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independence of software from hardware minimizes the deployment overhead for emerging protocols

Enabling protocol changes on-the-fly. Given the programmability from the PC host, WiMAC provides an easy user interface and permits the users to change between totally different MAC protocols while the testbed is operational.

Supporting cross-layer design. The MAC layer, that is an interface between the link layer and, therefore, the physical layer, is often tightly coupled with the underlying physical layer. Built on a dedicated FPGA, WiMAC provides enough freedom for developers to reconfigure the physical layer, enabling protocol design across layers.

Fast prototyping. Based on the higher than 3 options, WiMAX lowers the barrier that presently blocks novel concepts from being enforced, serving to researchers implement new MAC protocols with short development time.

A novel cross-layer routing approach, MCORCA (Multi-Channel On-demand Routing with Coordinate Awareness), is given in [7] that utilizes multiple channels to enhance the performance of wireless ad-hoc networks. The planned cross-layer theme adapts the strategy of channel allocation and the mechanism of coping with conflicts. Channels are divided into a control channel and data channels; the control channel is employed for programming, and data channels are used for data transfers. MCORCA is an augmentation of an on-demand routing protocol for single channel wireless networks, referred to as ORCA (On-demand Routing with Coordinates Awareness). MCORCA notations are shown in Table 2 and flowchart is shown in Fig. 7.

Table 2: MCORCA Notations [7]

Notation	Description
u	a node
N	Total number of nodes in the network
C	The total number of available channels
CID	The assigned channel ID
t_0	The start time slot of switching to data channel
t_{RREQ}	The duration of route request RREQ
t_{RREP}	The duration of route reply RREP
t_{DATA}	The duration of data
N(u)	Set of one hop neighbors of u

The assigned channel ID is computed as follows

CID = (Rand ([1, N]) ⊕ Rand ([1, C])) mod C; where Rand ([1, N]) stands for random number generation between 1 and N.

An innovative cross-layer routing approach, MCORCA, for single NIC (Network Interface Card) multiple channel wireless networks is given. A single transceiver is assumed at every node. The goal of the design is to enhance network capability and shorten end-to-end delay by taking the benefits of concurrent data transmission in multiple channels. MCORCA exploits a distributed channel assignment methodology based on an existing on-demand routing protocol ORCA designed for the only NIC single channel MANET (Mobile ad hoc Network). Channels are therefore divided into 2 parts, a control channel, and multiple data channels, that are used for various tasks. In control channel, hello messages are periodically sent and channel reservation is assigned. All alternative channels are used for the transmission of routing packets and data packets. Once every node completes the task of either routing discovery process or data transmission,

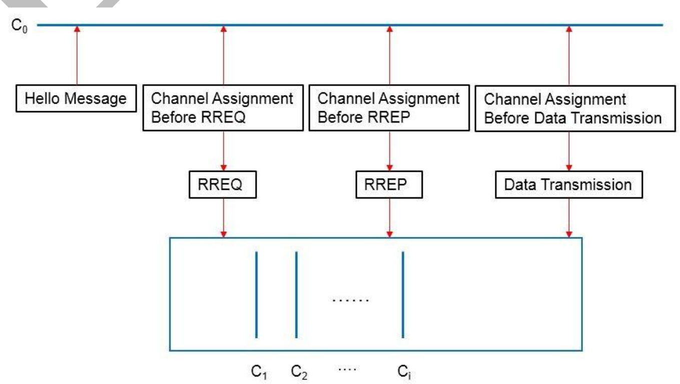

Figure 7: Flow Diagram of MCORCA [7]

MCORCA needs shift back to the control channel for a next assignment. Simulation results show that MCORCA improves network throughput well over ORCA by expeditiously allocating channels.

IV CONCLUSION

The cross-layer design techniques for wireless local area network are discussed. The cross-layer design represents a suitable technology to overcome some of the current

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limitations. Especially it is very true in the case of wireless networks. Its core idea is to preserve the functionalities associated to the original layers but to allow coordination, interaction and joint highest achievable performance 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 topic, research on cross-layering is still opening new perspectives, especially on architectural issues and dynamic adaptation of network behavior- but also on the trade-off between performance and interoperability. Based on the proposed analysis of ongoing efforts, the cross-layer design appears to be a suitable approach for future contributions in the framework of WLANs – able to address arising issues related to ever-higher performance, energy consumption, and mobility.

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