A GENERIC ADAPTATION LAYER FOR DIFFERENTIATED SERVICES AND IMPROVED PERFORMANCE IN WIRELESS NETWORKS

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Abstract - This paper focuses on the integration of Internet and Wireless LANs (WLANs) and proposes a novel technique that supports seamless and efficient integration. This technique is based on a generic adaptation layer, referred to as Wireless Adaptation Layer (WAL), which is introduced between the IP layer and the WLAN Link Layer. WAL is designed to (i) dynamically cope with the wireless channel impairments, (ii) provide QoS interworking between the IP infrastructure and the WLAN and (iii) be independent of the WLAN technology. These characteristics account for the advantages of WAL, namely, the improved performance, the wide applicability and the provisioning of differentiated services.

Keywords – Wireless Networks, QoS, IP, DiffServ

I. INTRODUCTION

Nowadays, the demand for mobile services experiences a ramping up growth, and therefore the technologies that provide wireless connectivity are of considerable importance. Especially Wireless Local Area Networks (WLANs), which offer wireless, high-bandwidth, indoor communications, are becoming more and more popular and tend to replace their wired counterparts. This fact has been recognized by several standardization bodies, which have responded by developing significant efforts in order to extend the capabilities of WLANs and to offer more advanced, secure and compatible services.

The evolution of Internet technology has also affected the development of WLANs considerably. One of the major issues today is the optimisation of WLANs to support Internet services, especially advanced IPv6 services and Quality of Service (QoS). This paper addresses this issue and proposes a QoS support mechanism for WLANs based on DiffServ that is both transparent to the upper and lower layers, as well as adaptive to the varying conditions of the wireless channel. The mechanism is described in conjunction with the Wireless Adaptation Layer (WAL) [1], that aims at coping with the wireless channel impairments and provide better QoS to different kinds of traffic, but it can also be considered with other QoS improving techniques.

The rest of the paper is organized as follows: Section 2 sets the framework of the proposed mechanism and describes the overall architecture. Section III presents the specific aspects of the proposed solution. Finally, section 4 contains our conclusions.

II. WAL ARCHITECTURE

Several solutions are available in the literature, coping with limitations of the wireless links. Most of these solutions propose enhancements at the Transport or Application layers, while others focus on the Link Layer trying to transparently improve higher layers performance and thus avoid modifications [2]. A number of these solutions fall into the category of Performance Enhancing Proxies (PEPs) that are defined as elements used to improve the performance of Internet Protocols on network paths where native performance suffers due to characteristics of a link or subnetwork path [3].

The approach proposed in this work is in line with the idea of PEPs but also tries to expand and generalise it. More specifically, it is based on the introduction of an intermediate layer called Wireless Adaptation Layer (WAL) between the IP and the Link Layer. WAL incorporates a set of functional modules, viewed as generalised PEPs, that can be dynamically combined and adapted to the special characteristics of the wireless link and the transport protocol.

WAL architecture is shown in Fig 1. A novel and key feature of the WAL is that it is an abstraction used for service provisioning at the link layer. Each IP packet is classified by WAL into *chains* and *associations*. Service provision in the WAL is based on these two concepts, which are further discussed below.

A *WAL chain* defines the service offered to a particular set of IP packets and corresponds to a particular sequence of WAL modules that provide such a service. Classification of IP packets into a specific WAL chain is based on several parameters, such as the type of application traffic (e.g., audio/video streaming, bulk transfer, interactive transfer, Web) or the protocol type (e.g. TCP, UDP) etc. This classification is further explained in Section III.A

A *WAL association* identifies a stream of IP packets classified for the same WAL chain and destined to or originated from a specific mobile terminal (MT), i.e., *WAL_Association = <WAL_Chain, MT_Id>*. In other words, a WAL association corresponds to a particular type of service offered to a particular MT. In this way, we can differentiate the operation of WAL on a per-user basis. In addition, services for particular users can be customized to meet their specific QoS requirements and to implement a differentiated-charging policy.

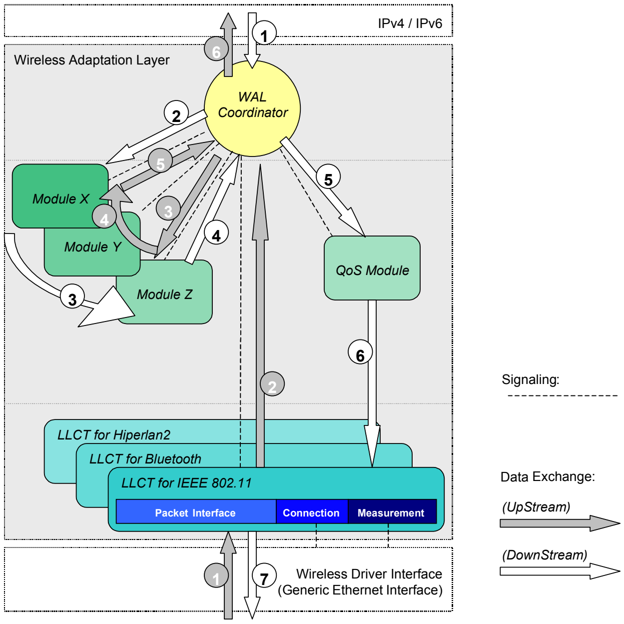

Fig 1. WAL Architecture

The WAL Coordinator shown in Fig 1 can be viewed as the central "intelligence" of the WAL. Both downstream (from IP layer) and upstream (to IP layer) traffic passes through the WAL Coordinator before being processed by other modules. In the downstream flow, the WAL Coordinator intercepts IP packets, decides on the WAL chain that these packets should pass through, and appends the WAL header, containing the information required for the operation of the modules. In the upstream flow, the WAL Coordinator accepts WAL frames (WAL Header + IP packet) and passes them through the sequence of modules, associated with the WAL chain, in the reverse order.

The QoS module (shown in Fig 1) provides flow isolation and fairness guarantees through traffic shaping and scheduling.

On the other hand, modules X/Y/Z comprise a pool of functional modules, aiming to improve performance in a number of ways. The modules that have been identified so far are:

- **ARQ module (ARQ)**: Can be used to improve packet error rate of non-real-time traffic (for example interactive or best-effort).
- **FEC module (FEC)**: Its use is recommended for real-time-traffic (usually conversational and streaming) because it can reduce packet error rate without increasing delays like ARQ.
- **Fragmentation module (FRM)**: Can decide on the recommended fragment length based on channel conditions.
- **IP Header Compression module (HC)**: This module can be used to reduce the overall header overhead, leading to increase of the available bandwidth.
- **SNOOP module (SNP)**: Snoop is a popular performance improvement method for TCP, and as such it can also be used in the case of WAL.
- **QoS module**: Used to prioritise traffic, in order to maintain delay constraints, especially of real-time traffic.

Finally, in order to interface with a number of wireless drivers of different wireless technologies (such as IEEE 802.11, Bluetooth, HiperLAN/2, etc.), one Logical Link Control Translator (LLCT) module for each different wireless technology has been introduced. The main functions of this module manage the connection status with the wireless driver, and ensure the stream conversions toward the wireless driver. A more detailed description of WAL can be found in [1].

III. SERVICE DIFFERENTIATION IN WAL

A. Classification of IP Traffic within WAL

For the classification of the IP packets to WAL chains a service differentiation is needed. Service differentiation in WAL is based on the DiffServ architecture. In this respect, the wireless access system can be viewed as a DiffServ domain with the Access Point (AP) acting as the DiffServ boundary node, interconnecting the wireless access system with the core network or other DiffServ domains [4, 5].

The first step for introducing the DiffServ architecture in WAL is the definition of a suitable classification scheme that classifies incoming traffic to different DiffServ classes. In this way, WAL can provide each flow with a different level of service that will better meet its needs. Further to this, DiffServ reduces significantly the amount of state information that needs to be maintained and facilitates the handling of many different data streams that can be grouped and handled as a single stream [6].

According to the DiffServ model, IP traffic entering a network is classified and possibly shaped and conditioned at the boundaries of the network, and assigned to different behaviour aggregates. Each behaviour aggregate is identified by a single 8-bit DiffServ code point (DSCP), contained in the IP header. Within the core of the network, packets are forwarded according to the Per-Hop Behaviour (PHB) associated with their DSCP.

Two of the most promising PHBs proposed within IETF are Assured Forwarding (AF) [7] and Expedited Forwarding (EF) [8]. The AF PHB provides delivery of IP packets in four, independently forwarded, AF classes. Within each AF class, an IP packet can be assigned one of three different levels of drop presence. So there are four classes with three different drop probabilities each. Therefore, twelve DSCPs have been reserved for this PHB group.

Table 1

Recommended codepoints for the AF PHB (xx= unused)

	Class I	Class II	Class III	Class IV
Low Drop	001010xx	010010xx	011010xx	100010xx
Med. Drop	001100xx	010100xx	011100xx	100100xx
High Drop	001110xx	010110xx	011110xx	100110xx

The EF PHB can be used to build a low latency, assured bandwidth, end-to-end service through DiffServ domains. This service appears to the endpoints like a point-to-point connection or a "virtual leased line", but it is not preferable for WAL since it is very demanding and may reserve a considerable part of the scarce available bandwidth of the wireless channel. Therefore, within WAL, IP packets with the EF PHB DSCP can be re-marked and mapped to AF PHB Class 1. For the shake of completeness, all other DSCPs not belonging to AF PHB group can be mapped to the default PHB (DSCP = 000000XX) which corresponds to the standard Best-Effort Service.

The proposed approach makes use of the AF PHB in order to classify the IP flows and provide a different service to each traffic type. In this approach four types of service are mapped to the four main classes of AF PHB:

- **Conversational** (e.g., Voice over IP) →**AF Class I**
- **Streaming** (e.g., Video streaming) →**AF Class II**
- **Interactive** (e.g., Web Browsing) →**AF Class III**
- **Best effort** (e.g., Mail, Telnet, FTP) →**AF Class IV**

For more flexibility and adaptability, additional discrimination of IP flows is based on the Protocol Type. For example, TCP flows can utilize specific WAL modules (e.g., SNOOP) that are not applicable to other types of transport protocols.

The mapping of each DSCP/Protocol Type combination to the corresponding WAL chain is shown in Table 2.Notice that WAL Chains III and IV are subdivided into subclasses *a* and *b* based on the Protocol Type, in order to take advantage of the specific WAL modules that are available for TCP flows in WAL.

Table 2

Mapping of DSCPs/Protocol Types to WAL Chains.

Service Type	DS AF Class	DiffServ CodePoint	Protocol Type	WAL Chain
Conversational	AF I	(001)010XX (001)100XX (001)110XX	Any	WC I
Streaming	AF II	(010)010XX (010)100XX (010)110XX	Any	WC II
Interactive	AF III	(011)010XX (011)100XX (011)110XX	Non-TCP	WC IIIa
Interactive	AF III	(011)010XX (011)100XX (011)110XX	TCP	WC IIIb
Best effort	AF IV Default	(100)010XX (100)100XX (100)110XX 000000XX	Non-TCP	WC IVa
Best effort	AF IV Default	(100)010XX (100)100XX (100)110XX 000000XX	TCP	WC IVb

B. The concept of WAL Module chains

Each WAL chain consists of a number of WAL modules that are interconnected and combined together so as to improve the level of QoS provision for a specific type of IP traffic.

Each IP packet entering the WAL is classified to the corresponding WAL Chain as shown in Table 2. After classification, the WAL Coordinator forwards the incoming packets to the first module of the chain. Each module in the chain performs its corresponding action on the packet (e.g., FEC module adds CRC bytes), and returns the packet to the WAL Coordinator that passes it to the next module in the chain. At the receiving side the packet traverses the module chain in the reverse order.

Fig. 2 shows examples of some possible WAL chains that can be employed with respect to the proposed classification scheme. Note that the QoS module is always placed last in every WAL chain so as to guarantee that the scheduled packets will be ready for transmission and will not experience any further delays within WAL, due to processing or queuing in other modules.

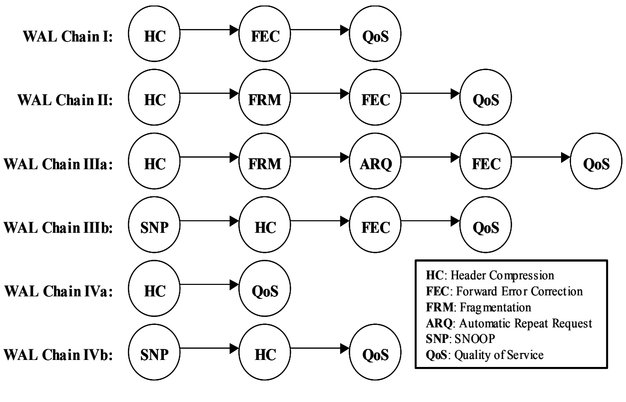

Fig. 2 Proposed module chains for each WAL Chain

The choice of the modules in each chain is based on the nature and requirements of each service type, such as delay and loss requirements. The order of the modules is chosen so that the preceding modules do not cause conflict or degrade the operation of the succeeding ones. These module chains are just a few of the possible chains that may be utilized in order to improve the performance of WAL. Since the classification scheme can be further refined a set of possible module chains that will better fit to the specific requirements will be defined in the future.

The parameters of each module are set so as to optimise the system performance under the current channel conditions and the volume of traffic. In order to adapt to the changing channel conditions or user requirements (in terms of QoS level, or requested bandwidth) the parameters of each module can be set dynamically. The procedures of setting and dynamically adapting the parameters of WAL modules are called Association and Re-Association respectively and are described below.

C. Association Establishment in WAL

In order to establish a new association, WAL Coordinator needs to exchange information with its peer, so as to determine the module parameters that will be used. These parameters should be accepted by both parts, before a new association can be established. This need for information exchange within the wireless access DiffServ domain imposes the need for the existence of an explicit signaling scheme between the AP and the MT.

The proposed signaling scheme in WAL is a three-way handshake:

i) The initiating side issues an ASSOCIATION-REQUEST message indicating the Association ID, the requested bandwidth, as well as a set of proposed modules and parameters (based on the current channel condition). The requested bandwidth can be considered also as parameter of the QoS module in order to define queuing priorities.

ii) The receiving side responds with an ASSOCIATION-RESPONSE message, indicating the establishment of the association and returning a set of negotiated module parameters.

The initiating side issues either an ASSOCIATION-CONFIRM message, confirming that the parameters are accepted or an ASSOCIATION-REJECT message indicating that the returned association parameters can not be accepted. In this case both sides release the association.

The signaling exchange during the association establishment is depicted in Fig.3.

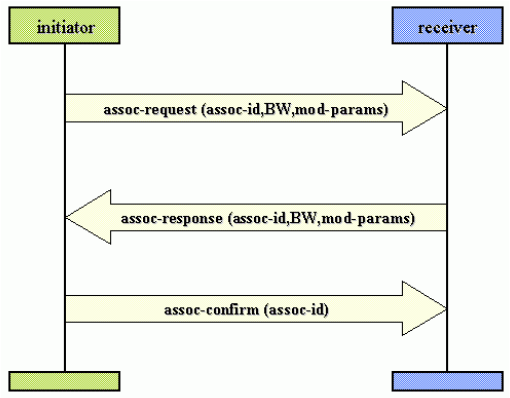

Fig.3 Signaling Exchange during Association Establishment

D. Re-Association procedure in WAL

The Re-Association procedure aims to adapt module parameters and may be triggered by the AP or MT WAL Coordinator when:

i) it detects a significant change of channel conditions, or

ii) the volume of incoming traffic increases/decreases over/below the specified limits.

For the Re-association procedure, a similar to Association, three-way handshake signaling scheme is used:

i) The initiating side issues a RE-ASSOCIATION-REQUEST message indicating, the Association Identifier, the new requested bandwidth (in case of change) as well as a new set of proposed module parameters (based on the current channel condition).

ii) The receiving side responds with a RE-ASSOCIATION-RESPONSE message, either accepting or proposing a new set of parameters.

iii) The initiating side issues either a RE-ASSOCIATION-CONFIRM message, confirming that the parameters are accepted or a RE-ASSOCIATION-REJECT message, indicating that the returned parameters are not accepted. In case the re-association is rejected, the initiating part can either Back-Off and retry later, relax the demands or move to another cell.

An important question, regarding the re-association procedure, is when and how often should it be invoked. Invoking the procedure very often (e.g., immediately after the traffic load changes or the channel condition deteriorates) may result in waste of bandwidth (due to extra signaling load) without attaining significant improvement of system performance. This is because the channel condition or traffic load may again return quickly to the previous state, thus eliminating the need for re-association. On the other hand, being insensitive to traffic or channel changes, may result in low system performance.

In the case of bandwidth re-allocation, a timer may be used, thus avoiding immediate invocation of the re-association procedure.

In case of module parameters adjustment, WAL Coordinator may keep the mean values of several statistic measures (e.g., throughput, channel utilization, Packet Loss, BER etc.) in order to determine the average channel state (e.g., Good, Bad, Very bad). When the average channel state is modified, the WAL Coordinator may decide to perform a re-association.

IV. CONCLUSIONS

The concept of traffic classification and proper adaptation for wireless networks has been presented focusing on (re)association procedures. The operation is based on WAL, an intermediate layer between the Link Layer and the IP Layer aiming (i) to provide different level of services to IP traffic exchanged between a fixed IP network and a WLAN and (ii) to provide improved performance in a wireless IP environment. These features renders WAL an attractive and promising solution for next generation wireless networks, which would mandate efficient interworking with fixed IP networks and QoS interworking capabilities. In addition, it was shown that WAL offers a solution that does not require any enhancements or modifications to the existing IP layer as well as to the existing WLAN technologies. Therefore, it can be transparently applied to systems being currently in operation. Moreover, WAL features a highly modular architecture and can be easily adapted and extended in order to meet a vast range of requirements.

QoS in WAL is based on the DiffServ architecture. A classification scheme based on AF PHB is defined for determining the class of each incoming IP packet. Each AF PHB class is mapped to a WAL chain on order to have the same treatment. A major aspect of WAL is its adaptability to the ever-changing wireless channel conditions and bandwidth requirements. This is achieved through the Association and Re-Association procedures that are used to adapt the parameters of WAL modules to the current channel state and the requirements of the mobile user. These procedures impose the need of an explicit signaling scheme between the AP and the MT. In WAL this scheme is realized through a three-way handshake message exchange between the peer WAL entities.

In general, WAL defines a novel and generic approach that can support the efficient migration of IP to wireless environments. In this paper, we illustrated its most prominent characteristics and capabilities. Further work will investigate the performance of WAL against the “non-WAL” case through extensive simulation, as well as the evaluation and optimization of WAL module chains. In addition, the re-association procedure will need to be further investigated and determine the criteria and the optimum conditions for triggering this procedure.

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REFERENCES

[1] P. Mähönen, T. Saarinen, N. Passas, G. Orphanos, L. Muñoz, M. García, A. Marshall, D. Melpignano, T. Inzerilli, F. Lucas, M. Vitiello, “Platform-Independent IP Transmission over Wireless Networks: The WINE Approach”, *IEEE Personal Communications Mag.*,Vol.8 No.6, December 2001

[2] G. Xylomenos, G.C.Polyzos, “Link Layer Support for Quality of Service on Wireless Internet Links”, *IEEE Personal Communications Mag.*, October 1999

[3] RFC3135 J. Border, M. Kojo, J. Griner, G. Montenegro, and Z. Shelby, “Performance Enhancing Proxies Intended to Mitigate Link-Related Degradations” June 2001.

[4] RFC2475, S. Blake, D. Black, M. Carlson, E. Davies, Z. Wang, W. Weiss. “An Architecture for Differentiated Service”, December 1998.

[5] RFC2474, K. Nichols, S. Blake, F. Baker, D. Black, “Definition of the Differentiated Services Field (DiffServ Field) in the IPv4 and IPv6 Headers”, December 1998.

[6] D. Skyrianoglou, N. Passas and S. Kampouridou, "A DiffServ-based Classification Scheme for Internet Traffic Over Wireless Links", in *proc. ICWLHN 2001*, Singapore, December 2001.

[7] RFC2597, J. Heinanen, F. Baker, W. Weiss, J. Wroclawski, “Assured Forwarding PHB Group”, June 1999.

[8] RFC2598, V. Jacobson, K. Nichols, K. Poduri, “An Expedited Forwarding PHB”, June 1999.