Wireless Internet

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Abstract

Wireless Internet extents the transportation medium of the traditional Internet. Wireless environment creates new, unpredictable problems as it's nature differs from the well researched wireline connections of the modern Internet. The optimisation of the wireless networking is an undergoing research challenge.

This paper discusses the wireless connection's properties versus wireline connections with IP-based protocols. First the paper discusses about the challenges wireless connection creates for the classical IP both in the wireless LANs and wireless WANs.

One W-LAN (802.11) and two non-TCP based solutions (MOWGLI, WAP) based on the W-WAN links are described as solutions to the wireless problem.

1 Introduction

Mobile computing and wireless networking is expected to see a vast growth in a near future. Mobile computing is becoming more lucrative as portable computers and personal communicators evolve as well as wireless links. However the current Internet networking protocols are optimised for wired networks [1]. Mobility in IP has been a very recent add [2].

This paper approaches the Wireless Internet theme by discussing the wired versus the wireless environment characteristics and the problems current protocols face in the wireless environment. One wireless LAN and two non-ip approaches are represented as solutions to the wireless computing needs.

1.1 Architecture

The mobile wireless networks can be grouped to W-LANs and W-WANs. This paper's viewpoint to wireless environment is

- a wireless mobile device (also a mobile node) [5]
- a wireless link
- a base station
- a wireline link and the landline Internet

The mobile device is connected to the wireline Internet via a wireless link.

The W-LAN wireless link can be IEEE 802.11 compliant network [4]. The WaveLan consists of

- an access point
- a mobile node (laptop, desktop)
- and possibly wireless-to-wireless or wireless-to-ethernet bridges

where the wireless link is usually tens of meters. Further the same semantics is used through the paper to describe the wireless, mobile environment.

The W-WANs have typically four to five times longer wireless link than the W-LANs. Examples of the W-WANs are CDPD, Ricochet, CDMA, PHS, DoCoMo, GSM, Tetra, GPRS and Wireless ATM.

This paper does not consider satellite links. The satellite links properties differ from W-WANs, for example offering higher bandwidth than the current W-WANs.

1.2 Wireless Link

The wireless link may usually present higher bit error rate than the wireline one. The wireless link may also have burst errors and disconnections [1].

The wireless service is usually circuit switch oriented as opposed to the Internet's packet network. Wireless packet networks are starting to appear, for example CDPD, Tetra and GSM's GPRS.

The reliability of the wireless link varies. Typically a packet is retransmitted till the target acknowledges it. Weak reliability, even temporary disconnections and high variability in transmission are the most problematic issues.

2 Internet Protocol

The IP protocols are optimised to the megabit per second wireline connections. Wireless links have usually substantially lower throughput, only kilobits in seconds.

The IP packets are protected by a relatively weak check sum. Because of the low level of the link robustness in wireless environment it might be undesirable to send a IP packet to the destination only to be discarded at the endpoint. The end-to-end detection of the network error semantics does not fully utilise the wireless link.

2.1 Proprietary solutions to Wireless Internet

WAP is an architecture to bring Internet content and advanced services to the digital cellular phones and other wireless devices, for example personal communicators [ref]. WAP (Wireless Application Protocol) is an undergoing task, originated by Ericsson , Motorola, Nokia and Unwired Planet. In stead of IP or HTTP, WAP has alternate optimised protocols over wireless link. WAP relies on the base station or to an intermediate agent to provide access to the Internet.

MOWGLI (The Mobile Office Workstations using GSM Links) aimed higher end targets than WAP [ref]. Mowgli preserves the socket sematics, but specifies its own underlying transport. Mowgli aimed to change the client-server semantics to client-mediator-server sematics as well as peer-to-peer to peer-to-peer-thru-mediator paradigm. Also Mowgli is later shortly represented.

2.2 IP-based Wireless Internet

Forward error correction, retransmissions and acknowledges improve the link layer services. The Point-to-Point Protocol (PPP) with robust framing and checksumming is a straightforward way to connect the to the Internet. However, the wireless link, for example GSM, may solve the mobility but be economically unattractive.

MobileIP is enhances the IP protocol [2]. MobileIP allows transparent routing of IP datagrams to and from the mobile node. The key components of the standard are Home Agent (HA) located at the home network of the mobile node and the Foreign Agent located at the network, which the mobile node is connected to. The mobile node registers its new location through the foreign agent to the home agent. The home agent hides the mobility by intercepting incoming packets in the home network and tunnelling packets to the mobile nodes new location. The standard proposal considers security, authentication and routing optimisation as well as basic mobility [2], [3]. As a criticism against MobileIP it is aimed as a link level addressing and routing solution to hide mobility.

As well as PPP and MobileIP itself do not solve the presented problems with the wireless link.

Path MTU discovery allows the sender to determine the maximum end-to-end transmission unit. Using larger MTU size than the default 512 lowers the ratio of header overhead to data and it allows TCP to grow its congestion window faster by increasing it segmental. Larger MTU has correspondingly higher error probability.

3 Considering TCP

The wireless environment's characteristics propagate problems to TCP level. TCP does not perform well in presence of the non-congestion loss. The overhead of the TCP may be too much for a "thin" wireless link. Also TCP can be considered as a heavy solution to a lightweight portable device to fix the wireless problems.

For compatibility it is preferable to continue using the same protocol that the rest of the Internet uses. Any extensions specific to the wireless link may be negotiated. At the link layer the forwarding error correction and ARQ can be used to reduce bit error rate to level so that TCP sees all errors as congestion. Most of the W-WAN techonologies support this.

MobileIP hides the handoffs of the different techonologies, but only if the same protocols (TCP/IP) are used throughout. Also can be claimed that the TCP has been research and experieced more thorougly than the newer alternative technologies.

3.1 Optimisation

The proposed slow start termination or modifying (T/TCP: RFC1397, RCF1644) over a wireless link may cause an increased congestion level in the Internet, if it is widely accepted. The slightly increased initial window with immediate ACK of the first segment increases the wireless links utilisation, especially when using several shortliving connections. For example the HTTP/1.1 solves the slow start problem with persistent connections.

TCP header can be compressed in PPP. TCP header compression for the PPP is at the moment a proposed standard. Also the IP payload compression is a proposed standard. Some of the payloads are already compressed, for example in FTP transfers as well as most of the transferred pictures are already compressed (JPEG,GIF). Also higher level protocols might compress the data before IP-level.

Fast retransmit and fast recovery (RFC2001) ensure the congestion avoidance of the TCP, but help adjust the send window to the correct segment when it is lost [6]. The sender retransmits the missing segment after it receives several duplicate ACKs and moves fast recovery mode, not to the slow start mode.

Other considerable optimisations:

Scheduling algorithms

- fairness: fair queuing, class-based queuing
- throughput

Spoofing combined with split TCP and performance-enchancing proxies

- I-TCP
- SNOOP (split/link layer reliability)
- WTCP
- MOWGLI, WAP

Compression methods:

Header compression alternatives

- Van Jacobson (RFC 1144)
- tcp + ip: improve interactive response time, small packets for bulk data, small packets for low data-rate traffic, decrease header overhead (with MTU 512 overhead decreases from 11,7% to 1%), reduce packet loss

IP payload compression (above)

4 Wireless Local Access Network

4.1 The IEEE 802.11 architecture

Wireless Local Access Network protocol is specified in IEEE 802.11 [4]. Wireless lan is based on cellular technology, underlying physical interfaces are two radio frequency protocols and one is based on infrared. The 802.11 specification covers MAC and physical layers.

The LAN is subdivided into cells. One cell is called Basic Service Set, BSS. One BSS is controlled by a Base Station, Access Point (AP). A wireless LAN can consist of the one BSS or several connected BSS's. The interconnecting backbone of the BSS is Distribution System (BS). Typically this is Ethernet. Standard calls the whole interconnecting wireless LAN as a Extended Service Set (ESS). This is described in the following picture.

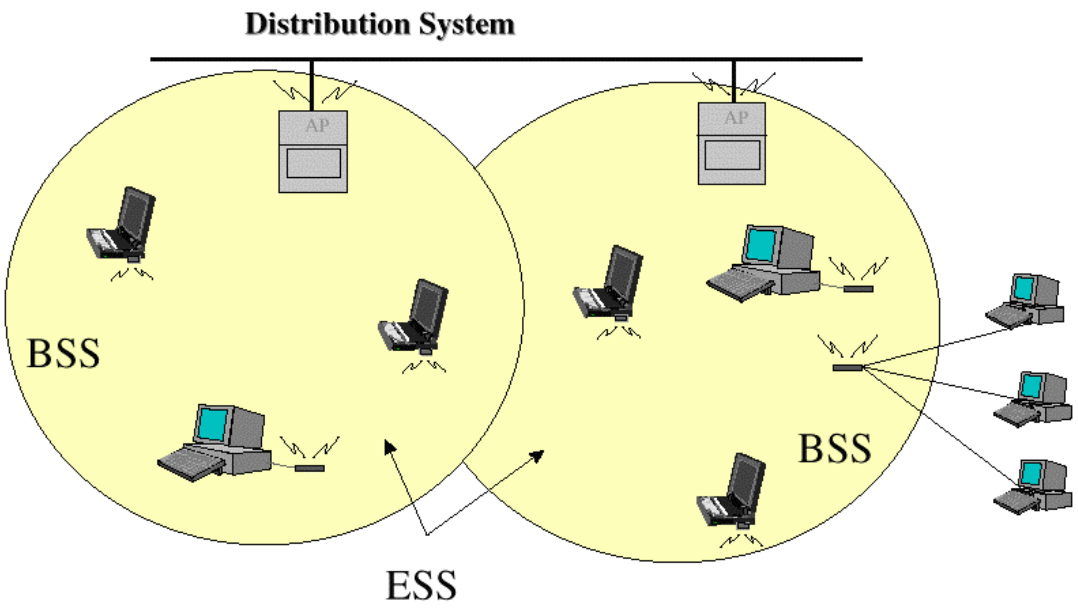

Figure 1 802.11 architecture

4.2 Layers

The 802.11 protocol consists of the medium access control layer (MAC) and physical layer. The MAC has additional functionality over the standard 802.3 MAC. The 802.11 MAC has enchanged reliability and error detection capabilities. It performs data fragmentation, packet retransmissions and additional acknowledgements to ensure reliability.

Physical layer can be frequency hopping spread spectrum (FHSS), direct sequence spread spectrum (DSSS) or an infrared running at 1 and 2 Mbps.

4.2.1 Medium access control layer

The common DSSS medium access control layer features are described shortly in the Table 1 802.11 MAC features:

Feature	**Benefit**
CSMA/CA with acknowledgement	Reliability
RTS/CTS	Robustness
Wireless distribution system	Coverage
Automatic rate selection	Coverage
Multi channel roaming	Mobility and performance
Fragmentation	Performance in severe conditions
Power management	Save battery life
Encryption based on RC4	Security

Table 1 802.11 MAC features

CSMA/CA with acknowledgement ensures that the packets are delivered to the destination end. The wireless system's higher error rate is coped with ack message.

Request to send/clear to send (RTS/CTS) mechanism ensures that only one station sends at given time. The ready to send work station requests permission to send. Request is delivered to every work station in a cell, and requesting work station starts transmitting after destination work station acknowledges the transmission request. Other workstations are quiet till transmission is over.

Totally wireless infrastructure can be gained with wireless distribution system. Access points can be connected with radio link to create a backbone connection. Coverage within a single cell can be increased with the automatic rate selection. A work station starts with 1Mbps connection and if more bandwidth is needed the density of the access points can be increased so that work station can use 2Mbps connection. See

Access node can support three overlapping channels within the same area offering totally 6Mbps bandwidth. A work station can roam from channel to channel as it can roam between cells. However the specification does not define how the roaming between cells should be performed! Hardware manufactures have added further roaming capabilities, but these are yet manufacturer hardware and software specific extensions [7], [8].

Message fragmentation increases performance in difficult environments. Retransmission of the short message is quicker than a long message, and possibly retransmission can be done between the gaps of an intermittent interferer. Fragmentation increases overhead in transmission. Fragmentation is configurable parameter in 802.11. Example of the interference source is a microwave oven: It operates 4ms and is silent 4ms at the same frequency area than the Wireless LAN.

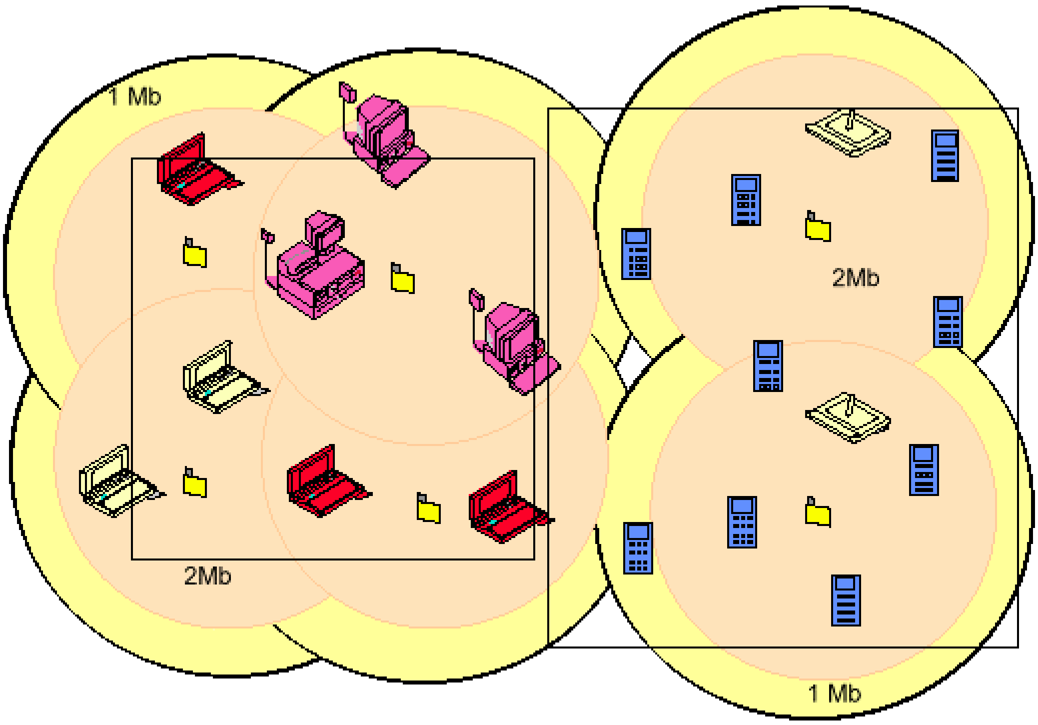

Figure 2 802.11 Multichannel roaming

Power management increases the battery life of the mobile work station. The wireless ethernet devices support sleep mode. Work station informs access node about sleep mode and during the sleep period the access node stores incoming messages. Work station checks the number of the stored messages by awakening shortly to receive a TIM (traffic information message) from the access node. Work station reads the stored messages and can resume sleep mode.

Security is based on RC4 encryption algorithm for the bit stream. Work station's access to the wireless network is authenticated by an access key.

4.3 Accuiring a wireless LAN

The following products were studied:

Aironet 3000 (11Mbps), 2000 series, bridges http://www.aironet.com/
Breeze: BreezeNET PRO.11 (3Mbps)http://www.breeze.com/
Lucent's WaveLAN (2Mbps) http://www.wavelan.com/

Card	**Price $**
Aironet Arlan655, ISA, 2Mbps	813
Aironet Arlan690, PCMCIA, 2Mbps	654
BreezeCom PCMCIA, 2Mbps	814
Lucent Wavelan ISA, 2Mbps	545
Lucent Wavelan PCMCIA, 2Mbps	495

Table 2 Wavelan adapters

Access Point	**Price $**
Aironet Arlan630, 2Mbps	1800
BreezeCOM, 3Mbps	2100
Lucent WavePOINT II, 2Mbps	900
Bridges	
Aironet wireless bridge, 4Mbps	3600
Aironet wireless bridge, 2Mbps	2100
BreezeCOM wireless bridge	2800 to 3300
Lucent WavePOINT II (ethernet to wireless)	1300
Wireless links	
BreezeLink 2Mbps, up to 50 km	5400

Table 3 Wavelan APs and bridges

5 Mowgli

The Mowgli-projects goal was to improve the utilisation of the wireless link (GSM) and create a efficient connection from the mobile node to the wired Internet [9]. This was gained by preserving the socket semantics, but changing everything underneath. The cellular network hides the terminal mobility. The GSM network handles location updates, handovers etc.

The Mowgli communication architecture replaces the client-server paradigm with client-mediator-server one as well as it replaces the peer-to-peer with peer-to-peer-thru-mediator.

5.1 Mowgli Communication Architecture

In the Mowgli communication architecture a mobile node is connected to the fixed network via a wireless telephone link. The Mobile-Connection Host (MCH) is a host in the fixed net providing the mobile node with the connection point to the wired Internet. A proxy in the MCH acts as a mediator to the mobile node.

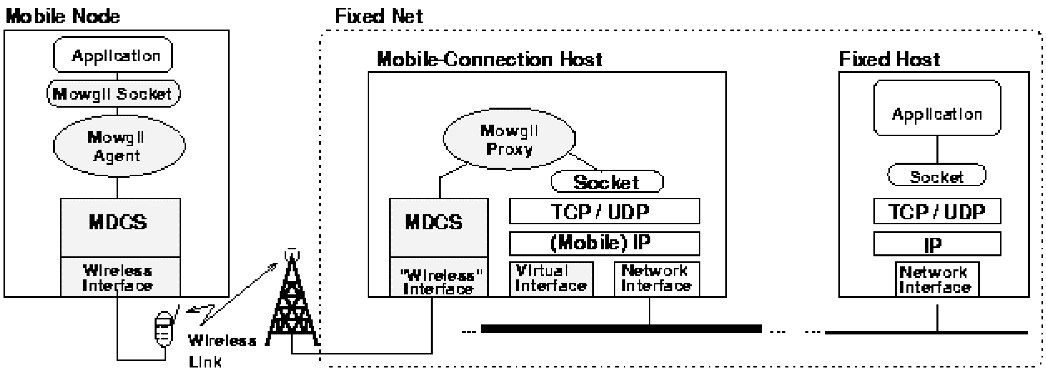

Figure 3 Mowgli architecture [9]

In the mobile nodes home network the MCH provides a dynamic virtual network interface for the mobile node. When mobile node connects to the foreign network's MCH, MobileIP is used to route IP datagrams. The Mowgli Data Channel Service (MDCS) offers the transport services over the wireless link.

The basic Mowgli software is implemented and usable in Linux.

5.2 Mowgli Data Channel Service

The Mowgli Data Channel Service offers bidirectional data channels for data transfer. The data channels can be opened as stream channels (TCP-like functionality) or as message channels (UDP-like). The MDCH supports 256 simultaneous data channels. Each of the channels has independent flow control. Multiplexing is prioritised by channel priorities, allowing reasonable response time to the interactive applications. The Mowgli specific socket API supports the enchanced MDCS functionality options.

The MDCS has improved fault tolerance. If the wireless link is disconnected, MDCS can resume the connections if needed. The MDCS maintains the state information of the opened transmission channels.

The enchanced data channel attributes (like priority, link reconnection, state expiration, idletime) allow simultaneous interactive usage with background file transmission. The MDCS supports cost effectiveness by closing the wireless link if idle.

5.3 Mowgli Data Channel Protocol

The communication over the wireless medium is defined in Mowgli Data Channel Protocol. It optimises the performance by minimising the protocol overhead (header, round –trip). The MDCP recovers from the unexpected disconnections and tolerates long high variably delays.

For example the protocol header in the data packet is only 1 to 3 bytes. Control packets average size is four bytes, a large variety of the packets guarantees the optimised packet size. The MDCP protocol can operate in two modes: In the default mode MDCP relies on lower protocol layers to provide error free data link. Acknowledges are needed only for flow control and to recover from disconnection. The other, more reliably mode, adds check sum to the packets.

The MDCP schedules data channels based on channel priority. Priority for each channel is static, which may cause problems with bursty interactive usage under a constant bulk transfer. Control packets have highest priority.

The flow control is based in the sliding window mechanism. Acknowledges are delayed until several packets can be acknowledged with a single ack packet. Difference to the TCP flow control is the slow acknowledgement. The receiving end acknowledges the packets when a certain amount of the send window is used and the receiving end has handled enough correctly arrived packets.

The recovery after unexpected disconnection handles both shot-term disconnections and more long-term disconnections. The MDCP signals Mowgli-aware clients about the wireless link disconnection.

5.4 Performance

The MDCP protocol was tested against TCP/IP on top of the PPP with header compression.

The performance was tested over a local area network as well as over a wireless link. Following table represents the results:

Single transfer for file of 100 kbytes, transfer times in seconds:

Net-work	Proto-col	From fixed host to mobile node				From mobile node to fixed host			
		Mean	**Min**	**Med**	**Max**	**Mean**	**Min**	**Med**	**Max**
LAN	**MDCP**	108,8	107,8	108,5	110,2	108,4	108,3	108,4	108,6
	TCP	139,2	116,6	143,1	168,2	126,3	114,4	114,7	160,5
WAN	**MDCP**	109,2	107,5	108,5	116,9	109,2	107,1	108,5	115,7
	TCP	171,9	117,6	154,6	252,7	231,2	121,4	152,6	497,1

Table 4 Single file transfer times

Three parallel transfers, file of 100 kbytes, transfer times in seconds:

Net-work	Proto-col	From fixed host to mobile node				From mobile node to fixed host			
		Mean	**Min**	**Med**	**Max**	**Mean**	**Min**	**Med**	**Max**
LAN	**MDCP**	326,4	320,8	326,2	330,4	331,5	315,8	324,2	494,3
	TCP	513,8	413,3	495,4	591,4	344,8	299,7	325,9	490,9
WAN	**MDCP**	328,5	254,6	325,6	385,2	339,7	307,4	324,1	584,8
	TCP	362,9	251,0	364,1	480,0	388,9	253,0	358,9	759,9

Table 5 Three concurrent file transfers

The results for interactive response time measurements were even more in favour to MDCP. The interactive response time was measured by sending one byte messages to TCP echo server in fixed host. The MDCP protocol was 10-50 % quicker than TCPs 7.88 second response times. At the same time with one byte messages a large bulk transfer was done over a ftp connection.

6 Wireless Application Protocol

The Wireless Application Protocol (WAP) is aimed to create a global wireless protocol specification that will work across differing wireless networking technologies [10]. The first specification was released in April 1998 [10].

WAP architecture's goal is to bring Internet content and advanced services to the digital cellular phones and other wireless devices, for example personal communicators. WAP (Wireless Application Protocol) is an undergoing task, originated by Ericsson , Motorola, Nokia and Unwired Planet. In stead of IP or HTTP, WAP has alternate optimised protocols over wireless link. WAP relies on the base station or to an intermediate agent to provide access to the Internet.

6.1 The WAP model

The WAP model consists of the WAP client, WAP gateway and the origin server. The WAP client recognises the standard URL reference to the origin server. The underlying WAP protocol converts the request and response to WAP content type specific modules at the edges of the wireless link. The WAP gateway is intended to be protocol specific, i.e. HTTP will have own gateway (proxy).

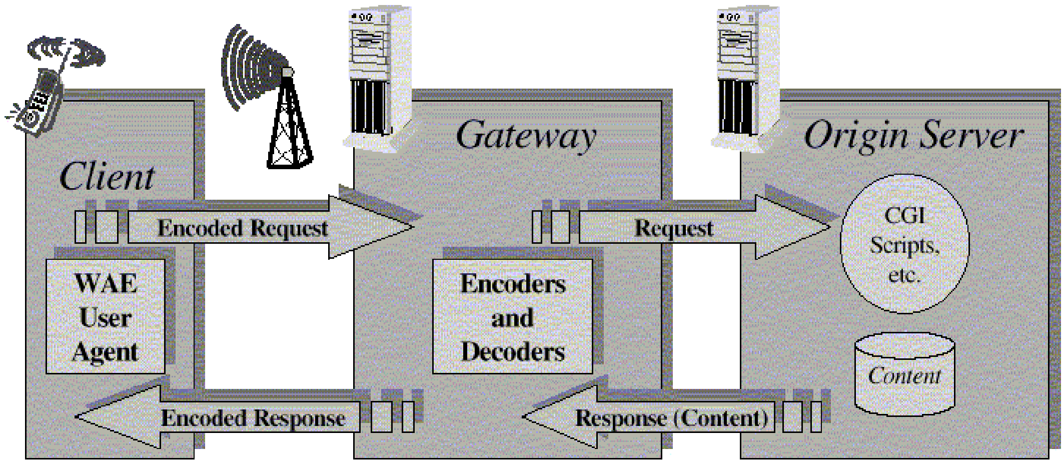

Figure 5 The WAP model

An example of the WAP network is in figure 6. The WAP client communicates with two servers. The other server is a WAP proxy connecting client to the HTTP-server. If the content from the web server is html, the html is converted to the WML (WAP specific wireless markup language).

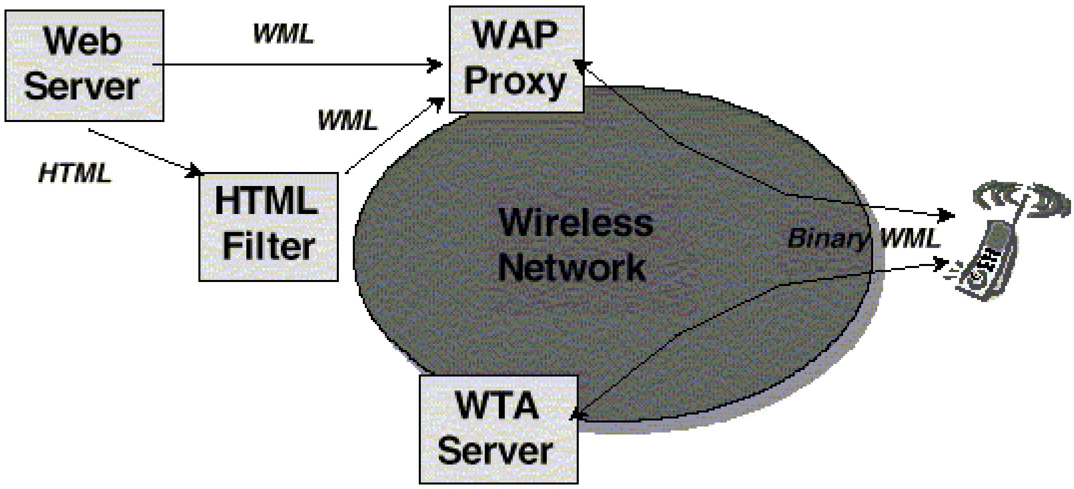

Figure 6 An example of the WAP network

6.2 WAP architecture

The WAP stack totally replaces the TCP/IP. The TCP/IP based Internet ends at the edge of the wireless link. The WAP protocol stack is represented in figure 7.

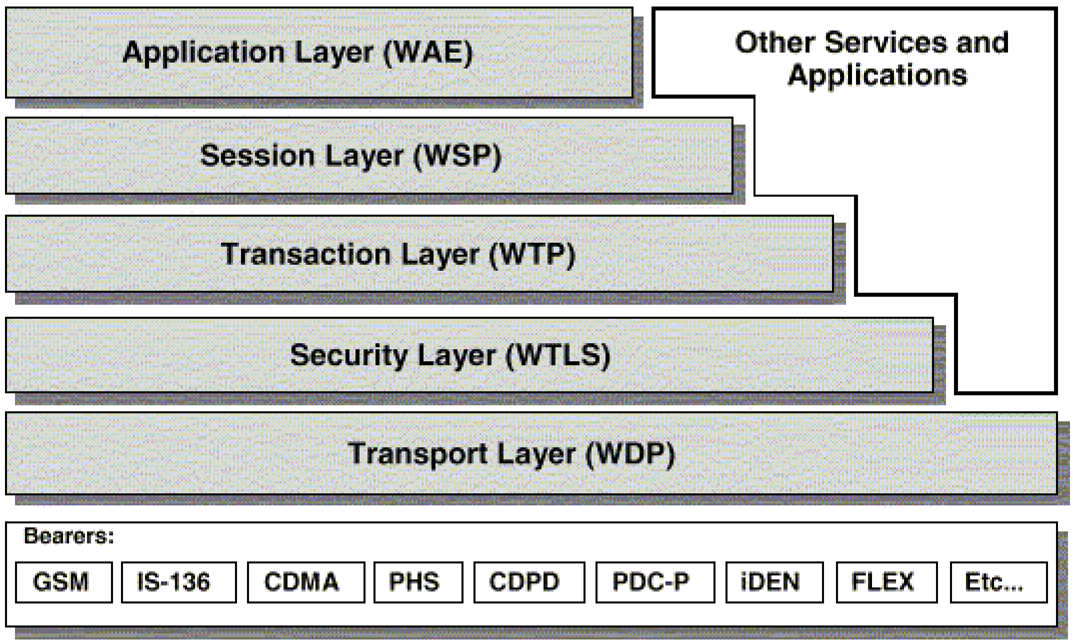

Figure 7 The WAP protocol stack

The Wireless Application Environment (WAE) is a mixture of WWW and mobile telephony technologies. The WAE is targeted to operators and service providers as a open API to develop on. The WAE contains

- Wireless Markup Language, WML, similar to HTML. WML is optimised to be used in handheld mobile terminals
- WMLScript
- Wireless Telephony Application

- Content formats

Through the WTA a WAP specific mobile phone is capable to normal telephony services. Following examples place an outgoing call through the WTA interface. Examples are in WML and WMLScript:

```
<WML>
<FORM>
     <DO TYPE=”ACCEPT” TASK=”GO”
          URL=”wtai:cc/mc;$(N)”/>

     Enter phone number:
     <INPUT TYPE=”TEXT” KEY=”N”/>
</FORM>
</WML>

<WML>
<COMMON>
<SCRIPT>
     function checkNumber(N) {
          if (Lang.isInt(N))
               WTAI.makeCall(N);
          else
               Dialog.alert(“Bad phone number”);
     }
</SCRIPT>
</COMMON>
<FORM>
     <DO TYPE=”ACCEPT” TASK=”GO”
          URL=”wtai:cc/mc;$(N)”/>
     Enter phone number:
     <INPUT TYPE=”TEXT” KEY=”N”/>
</FORM>
</WML>
```

Wireless Session Protocol (WSP) provides two sessions interfaces. The WSP protocols are optimised for low-bandwidth and long latency networks. The first interface is connection oriented (like TCP) and the other one is non-secure datagram based (like UDP). A subset of WSP is aimed for web browsing. The WSP/B supports HTTP/1.1 alike functionality and semantics with session suspend and resume capabilities.

The Wireless Transaction protocol is a light weight transaction oriented protocol. WTP offers following services:

- Transaction services
  - Unreliable one-way requests
  - Reliable two-way request
  - Reliable two-way request-reply transactions
- Optional message confirmation
- Out-of-band data on acknowledgements

- PDU concatenation
- Asynchronous transactions

The Wireless Transport Layer Security (WTLS) is based on Secure Sockets Layer (SSL). The WTLS is, again, optimised for "thin" communications channels. The WTLS may be used for secure communication between terminals, but the usage is optional. WTLS provides following features:

- Data integrity
- Privacy (encryption)
- Authentication
- Denial-of-Service protection

The Wireless Datagram Protocol is the transport layer. WDP offers interface for several bearer services in the various networks (GSM, GPRS). WDP supports several simultaneous connections over a given bearer networks. WDP has different bearer related profiles, which place the WDP specific protocol parts to most suitable network element level. The following two figures represent WDP utilisation over a GSM circuit switch data connection and over a GPRS.

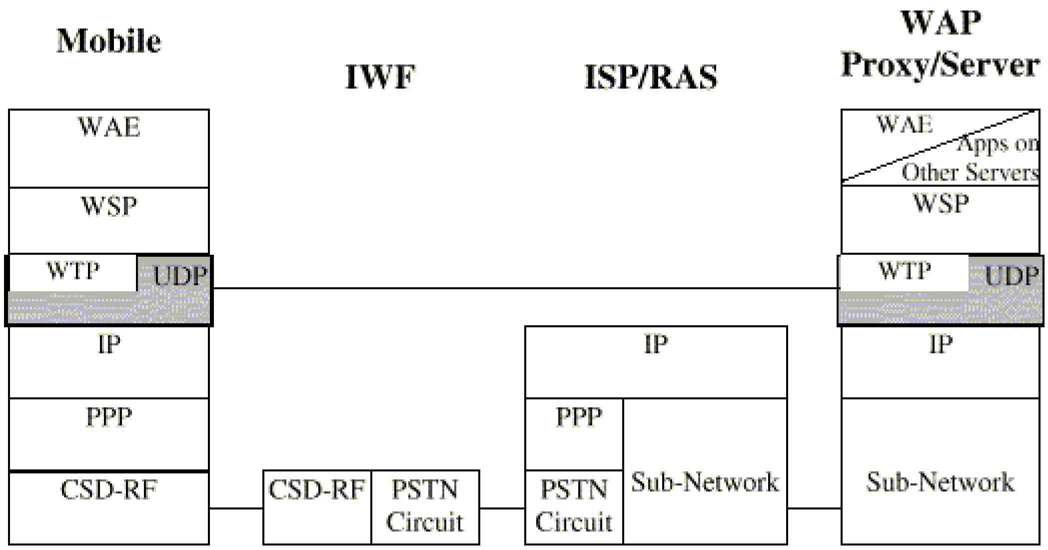

Figure 8 WDP over a GSM circuit switched data connection

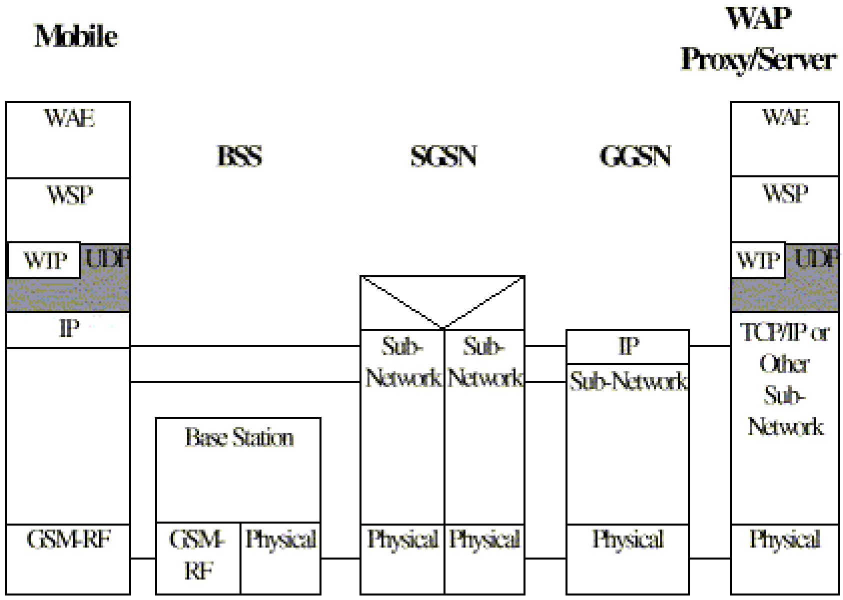

Figure 9 WDP over a GPRS

Figure ten represents three trivial WAP stack users.

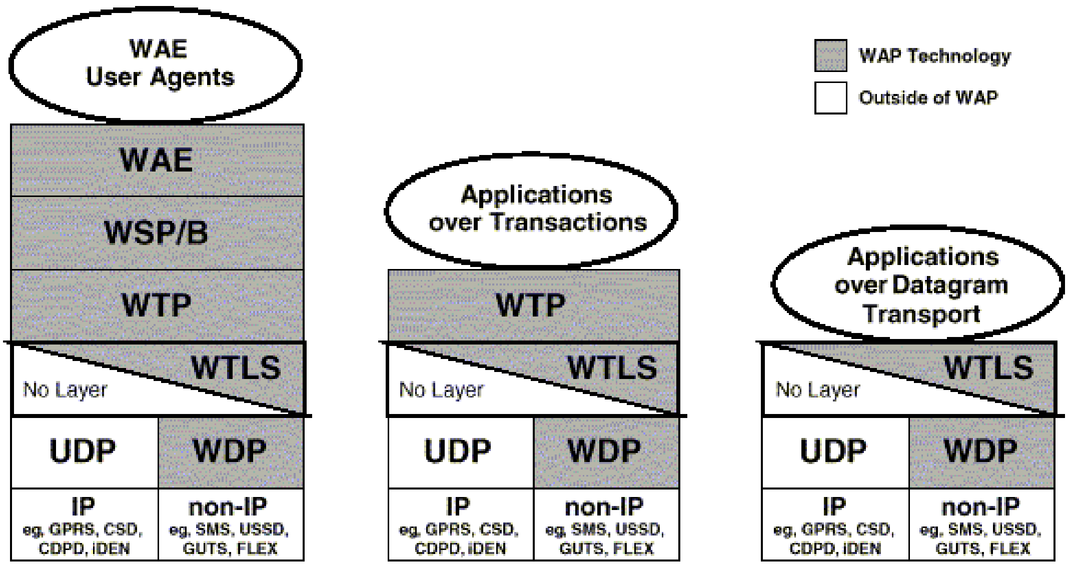

Figure 10 Sample WAP stack usage

7 Market charts

The wireless market's study was almost fruitless. The wireless local network hardware manufactures did not publish any figures or market information on their web pages. From the Datamonitor's 1997 Online connection media study a wireless connectivity remark was found.

From the same Datamonitor's study a LAN switch prognoses does not even mention wireless environment. In the table 7 Other –category is marginal, including wireless markets. The final graph represents the current and near future status of the Internet users, cellular subscribers and the number of the exchange lines.

7.1 The broadband future of online services

The broadband future of online services and Internet access in Europe (Datamonitor, 1997).

Households (000)	1996	1997	1998	1999	2000	2001
33,6 kb/s and below	2 625	4 715	7 239	8 050	7 100	5 200
56 kb/s + (analogue)		872	3 363	8 175	13 950	20 000
ISDN	375	872	1 749	2 725	3 450	3 800
Cable modems		116	485	1 262	2 408	4 000
XDSL		87	396	1 001	1 889	3 000
Digital sat./ wireless		29	135	348	733	1 200
Other broadband		18	84	238	469	800
Total	3 000	6 709	13 451	21 799	29 999	38 000

Table 6 Online connection media

7.1.1 Worldwide LAN switch market

USD millions	1995	1996	1997	1998	1999	2000	2001
ATM	140	340	650	1 020	1 340	1 700	2 000
10Mbps Ethernet	1 080	2 480	3 430	4 150	4 370	4 400	4 450
100Mbps Ethernet	80	240	610	1 350	2 700	3 900	5 100
Gigabit Ethernet	0	0	50	200	450	950	1 700
Token ring	100	260	450	600	600	550	450
IP / L3 switching	0	0	60	200	420	800	1 150
Other	100	200	330	400	450	400	350
Total	1 500	3 520	5 580	7 920	10 330	12 700	15 200

Table 7 LAN switch markets

Worldwide LAN switch market split by technology, 1995-2001 (Datamonitor, 07/97)

7.1.2 One world, three networks

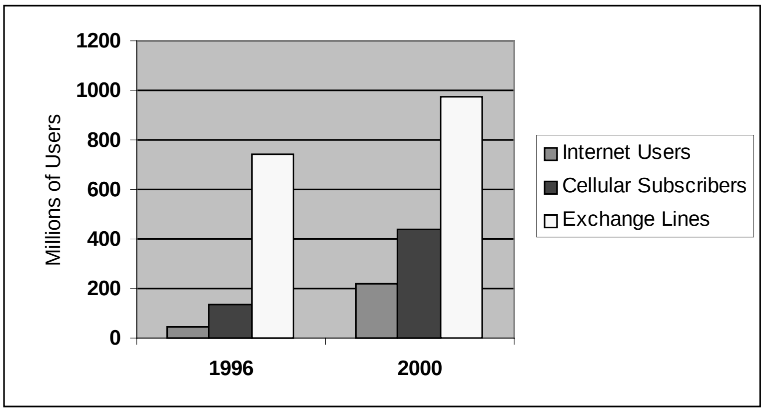

Figure 11 Different network users

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