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TESTING MODERN DATA TRANSFER TECHNOLOGIES IN  
MOBILE DEVICES

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# TESTING MODERN DATA TRANSFER TECHNOLOGIES IN MOBILE DEVICES

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The purpose of this Bachelor's thesis was to improve the software and methods developed for testing different network technologies used in smart phones.

Smart phones are thoroughly tested to assure smooth user experience and the best functionality. The test development in the networking area is a continuous process as new technologies and platforms are being simultaneously developed. The aim of this thesis was to improve the network test module called Sahti. Sahti is used for testing network technologies implemented in smart phones based on the Symbian OS.

The theoretical part of this thesis covers the used network technologies and the principles of software testing in general. The applied part of the thesis discusses the improvements made for Sahti's functionality, test cases, and documentation.

The work was successfully completed and the set goals were met. The test module now offers better user experience for test engineers along with new and improved test cases. Suitable corrections and additions were made both to the test case and test module documentation.

## MODERNIEN DATANSIIRTOTEKNOLOGIOIDEN TESTAUS MOBIILILAITTEISSA

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Tämän opinnäytetyön tarkoituksena oli syventää tekijän osaamista eri verkkoteknologioihin liittyen, sekä kehittää testauksessa käytettävää ohjelmistoa vaatimusten mukaan.

Älypuhelimia testataan kattavasti, jotta käytettävyys ja toiminnallisuus nousevat julkaisun vaatimalle tasolle. Verkkoteknologioihin liittyvä ohjelmistotestaus on jatkuva prosessi johtuen teknologioiden kehittymisestä sekä uusien ohjelmistoalustojen käyttöönotosta. Tämän lopputyön puitteissa pyrittiin parantamaan Sahti – testimoduulia. Sahdin avulla testataan matkapuhelinverkkojen ja eri tiedonsiirtoteknologioiden toimintaa Symbian pohjaisissa älypuhelimissa.

Opinnäytetyön teoriaosuus kattaa Suomessa yleisesti käytetyt verkkoteknologiat sekä ohjelmistotestauksen yleiset periaatteet. Käytännön työn sisältäneessä osuudessa käsitellään Sahtiin tehdyt parannukset, uusien testitapausten luonti, sekä dokumentaation päivittäminen.

Työ onnistui odotusten mukaan ja sille asetetut tavoitteet saavutettiin. Testimoduuli on nyt käytettävyydeltään parempi ja pitää sisällään vanhojen testien lisäksi joukon uusia. Testimoduulin ja yksittäisten testitapausten dokumentaatiota korjattiin tarpeen mukaan työn edetessä.

## FOREWORD

The work was done for Digia Plc, one of the largest software houses in Finland. Digia offers information and communication technology solutions worldwide, and is best known for its strength in developing software and solutions for smart mobile devices.

This thesis was written in English for the following reasons; for one, the books concerning the technologies in question are written in English. Secondly, the terminology has, at least for most parts, never been translated into Finnish. Basically I saw it easier and more sensible to have everything written in English. Now the thesis can be read by anyone, not just by native Finns.

The work done for this thesis has already shown to be very useful. My competence in the networking area has grown, making the work easier and hopefully more productive. I would like to thank both Yrjö Auramo (SAMK) and Vesa Poikajärvi (Digia) for the support and recommendations given regarding this thesis and for everyday work. I would also like to thank my common-law wife Riikka Rajala and my son Kaapo for bearing with me during the writing process.

Tampere, 7th January 2009

Joonas Jokinen

## ABBREVIATIONS

8-PSK	Octagonal Phase Shift Keying
16QAM	16 Quadrature Amplitude Modulation
2G	Second Generation
3G	Third Generation
3GPP	3rd Generation Partnership Project
64QAM	64 Quadrature Amplitude Modulation
8PSK	8 Phase Shift Keying
API	Application Program Interface
ATM	Asynchronous Transfer Mode
BS	Base Station
BSC	Base Station Controller
BSS	Base Station Subsystem
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CQI	Channel Quality Information
DCCH	Dedicated Control Channel
DCH	Dedicated Channel
DPCCH	Dedicated Physical Control Channel
DPCH	Dedicated Physical Channel
DPDCH	Dedicated Physical Data Channel
DSCH	Downlink Shared Channel
DTX	Discontinuous Transmission
E-AGCH	E-DCH Absolute Grant Channel
E-DCH	Enhanced uplink Dedicated Channel
E-DPCCH	E-DCH Dedicated Physical Control Channel
E-DPDCH	E-DCH Dedicated Physical Data Channel
E-HICH	E-DCH Hybrid ARQ Indicator Channel
E-RGCH	E-DCH Relative Grant Channel

EDGE	Enhanced Data-rates for GSM Evolution
EDGE	Enhanced Data-rate for Global Evolution
EGPRS	Enhanced GPRS
eMMC	Embedded MMC
ETSI	European Telecommunications Standards Institute
FACH	Forward Access Channel
GERAN	GSM/EDGE Radio Access Network
GGSN	Gateway GPRS Support Node
GMSK	Gaussian Minimum Shift Keying
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HARQ	Hybrid Automatic Repeat request
HLR	Home Location Register
HS-DPCCH	Uplink High-Speed Dedicated Physical Control Channel
HS-DSCH	High-Speed Downlink Shared Channel
HS-PDSCH	High-Speed Physical Downlink Shared Channel
HS-SCCH	High-Speed Shared Control Channel
HSDPA	High-Speed Downlink Packet Access
HSPA	High-Speed Packet Access
HSUPA	High-Speed Uplink Packet Access
IMSI	International Mobile Subscriber Identity
IP	Internet Protocol
ITU	International Telecommunication Union
LTE	Long-Term Evolution
LQC	Link Quality Control
MIMO	Multiple Input Multiple Output
MS	Mobile Station
MSC	Mobile Switching Centre
MSC/VLR	Mobile services Switching Centre/Visitor Location Register
OSS	Operations Support System
PTM-SC	Point-To-Multipoint Service Centre
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RACH	Random Access Channel

RAN	Radio Access Network
RF	Radio Frequency
RNC	Radio Network Controller
SGSN	Serving GPRS Support Node
SMS-GMSC	Short Message Service Gateway MSC
SNDCP	Sub-network Dependent Convergence Protocol
TCP	Transmission Control Protocol
TLLI	Temporary Logical Link Identity
TSG	Technical Specification Group
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UTRAN	UMTS Terrestrial Radio Access Network
WCDMA	Wideband CDMA
WiMAX	Worldwide Interoperability for Microwave Access

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## 1 INTRODUCTION

The purpose of this thesis is to review, evaluate, and improve the testing methods used in testing different data transfer technologies in mobile phones. It consists of the following three larger sections. These are the technical details of the data transfer technologies and the Symbian platform, theory and practise of software testing, and the improved test software.

During the past twenty years the cellular networks have improved greatly in terms of reliability, coverage, and efficiency. The fast development of smart phones has enabled the use of the Internet with speeds so far available only in homes or offices.

This thesis focuses on the different aspects of testing modern data transfer technologies in smart phones utilizing the Symbian platform. Testing is needed to ensure smooth operation when services offered by GSM or UMTS networks are used. This thesis will cover GSM and UMTS -based network technologies as they are used here in Finland.

The work consists of a review of the Sahti test module and the implementation of new features and test cases. Changes are made based on the findings and other requirements. Another objective of the thesis is to deepen the authors understanding of the subject area and thus support the everyday work in maintaining and improving the quality of testing in the networking area.

## 2 DATA TRANSFER TECHNOLOGIES IN MOBILE NETWORKS

### 2.1 Standardization

In order to make mobile networks, coding schemes, and data transfer technologies widely used, and easily adoptable standards have been created. Telecommunication standards are under constant development. Standardization organizations are collaborations of hundreds wireless operators and manufacturers from all over the world. GSM standardization was originally handled by European Telecommunications Standard Institute, ETSI. Later, the 3<sup>rd</sup> Generation Partnership Project (3GPP) has continued the standardization process with the GSM EDGE radio access network (GERAN) and UMTS terrestrial radio access network (UTRAN). /1/

GSM specification was done in two phases in order to have appropriate features on both the terminal and the network side. Some of the main features introduced in Phase 1 were basic telephony, emergency calls, data services (max. 9600 kbps), ciphering, authentication, and the short message service, SMS. Time division multiple access (TDMA) was chosen for GSM radio connectivity channel access method. With TDMA a piece of data is sent in one time slot while other slots are used by other clients. TDMA allows multiple simultaneous connections to be used on the same frequency channel. In order to reduce the required bit-rate for voice calls, linear predictive coding (LPC) was specified to be used. /1/

At the point when first GSM networks were built, the standardization continued to Phase 2. After October 1995, the Phase 2 specification was completed and new technical improvements were introduced. Line identification, call waiting, call hold and multi-party calls were some of the supplementary services introduced at the time. For allowing the evolution of the specification, the cross-phase compatibility and error-handling procedures were specified. /1/

After the summer of year 2000, work for the GSM radio specification was continued by the 3GPP. Transition was made in order to improve the standardization process. The standardization work was continued under a single organization to simplify and streamline the creation and evolution of the standards. The changes led to the

integration of WCDMA and GSM/EDGE, creating the multi-radio UMTS standard used today. /1/

The 3GPP organization consists of several different standardization organizations and the target is in creation of specifications for the global 3G cellular system. Technical work is done by operators and vendors in different technical specification groups (TSGs). Under the TSGs the specification work is shared between five working groups which all have domain specific responsibilities. /1/

## 2.2 GSM

GSM system was conceived and appeared mainly because there was a need for a unified standard for digital telephony system in Europe. It was to offer better performance, capacity, and cost efficiency while benefitting from utilizing the same technology in larger scale. Until the first phase of GSM was utilized, there were country- or area specific analog networks which offered poor compatibility towards each other. /2/

### 2.2.1 Infrastructure

The basic GSM network infrastructure is shown in Figure 1.

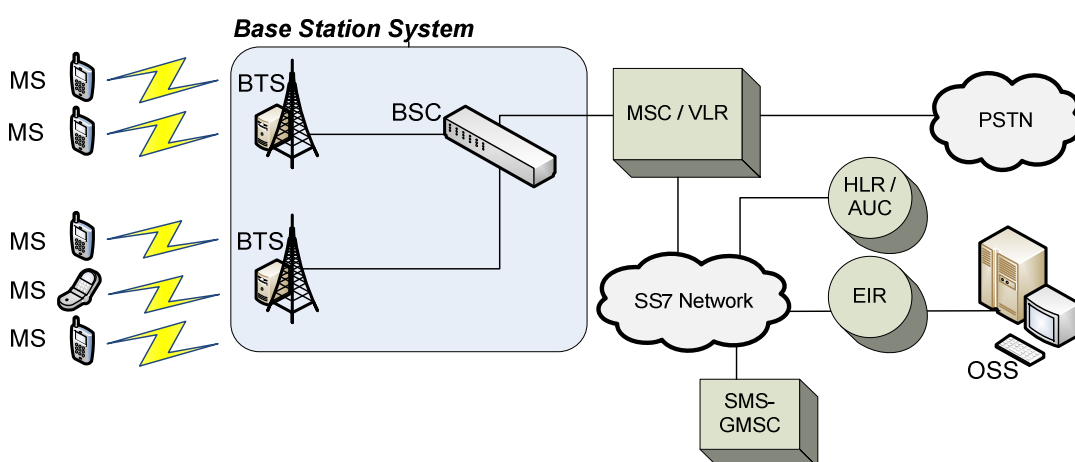


Figure 1. Basic GSM infrastructure. / 1, 3 /

The base station system has the functionality needed for establishing and maintaining radio connections to and from MS. It consists of multiple base station controllers (BSCs) and base transceiver stations (BTSs). The base transceiver station controls the radio interface between the transceiver, antenna and the MS. The BSC is a switch offering necessary control functions and a physical link between BTSs and the mobile services switching center (MSC). /1, 3/

Other system components handle the call processing and other subscriber related tasks. Some of the units are separate: the MSC, the visitor location register (VLR), the home location register (HLR), the authentication center (AUC), the equipment identity register (EIR), a short message service gateway MSC (SMSG-MSC), the signaling system number 7 (SS7), and the PSTN. /1, 3/

MSC handles telephony switching and controls incoming and outgoing calls between different telephone and data systems. VLR is integrated into the MSC and temporarily stores subscriber information in a database. Information about visiting subscribers is stored to enable faster service as HLR is not needed every time a call is made from the mobile station. HLR uses a database for storing and managing subscriber information. It is an important part of the network as it enables network access for the end-user. /1, 3/

The AUC is needed for ensuring confidentiality when a call is made. For this purpose there are authentication and encryption parameters for verifying identities and protecting the security of each caller. The EIR is used to store identification information of the MS. This enables the service provider to prohibit calls from stolen or otherwise unauthorized mobile stations. The SS7 is a telecommunications protocol for transmitting digital data on a broadband network /1, 3/.

Text messages are operated through the short message service gateway MSC (SMS-GMSC). The operation and support system (OSS) is a tool for configuring and monitoring the system. The OSS is needed when small- or large scale maintenance operations are done for the GSM network. The PSTN (Public Switched Telephone Network) stands for the regular old-fashioned telephone system. /1/

### 2.2.2 HSCSD

In the first phase of the GSM specification only a very basic support for data transfer was offered. The data transfer rate was limited to 9.6 kbps using a single time-slot. The HSCSD was the first Phase 2+ specification item using higher data-rates./1/

The principle behind the HSCSD is that multiple full-rate traffic channels (TCH/F) are allocated for data transfer. The data is split and combined from separate data streams. These streams are transferred by n number of channels in the radio interface, where  $n = 1, 2, 3 \dots 8$ . Figure 2 shows the basic HSCSD architecture. Data streams are transferred independently and combined later to match the original data. Modulation and coding in the radio interface enables the use of higher bit-rates for a single GSM time slot. Thus, with 14.4 kbps channel coding and eight channels, the maximum radio interface bit-rate for HSCSD is 115.2 kbps. Because of the limitations on the network side, the maximum bit-rate is limited to 64 kbps. /1/

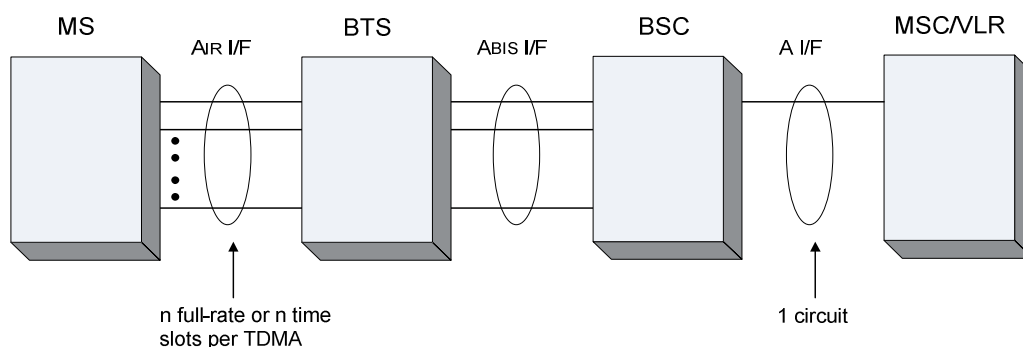


Figure 2. Network architecture for supporting HSCSD connections /4/.

Because the HSCSD configuration uses multiple traffic channels, the cost for using the service is usually high for the end-user: customers are charged by the connection time. The HSCSD also has a long access time to the network which might have a negative impact for some services that require fast access times. Furthermore, it needs to be noted that voice calls have higher priority, which in some cases can lead to the disconnection of the HSCSD connection. /1/

The usage of the HSCSD in modern GSM networks is limited since other data transfer technologies offer higher data transfer rates with lower cost. The GPRS provides faster data transfer rates and is more cost efficient when compared to the HSCSD. /1/

### 2.2.3 GPRS

Soon after the introduction of GSM networks it was realized that circuit-switched data services were not to last. Packet-switched networks like the GPRS use bandwidth and resources only when needed and have very fast access times to the network, unlike the HSCSD, for example. /1/

By using the GPRS for data transfers, the end-user can access different networks with protocols like the TCP/IP for Internet. Mobile stations with GPRS can use up to eight traffic channels over the air. Channels are dynamically allocated when there is data to download or upload. The GPRS can be used to send SMS messages and to get anonymous access to network. Theoretical maximum for throughput is 160 kbps but requires using all eight traffic channels and disabling error correction. /1/

The GSM system was designed mainly for making voice calls. This means that GPRS system had to be implemented on top of the existing network elements. The GPRS-specific functionality remains hidden from the external networks and the GPRS system is seen as any other normal sub-network by other networks, mainly the Internet. /1/

The network architecture of the GPRS is portrayed in Figure 3. The most important parts implemented were the serving GPRS support node (SGSN), the gateway support node (GGSN) and point-to-multipoint service centre (PTM-SC). /1/

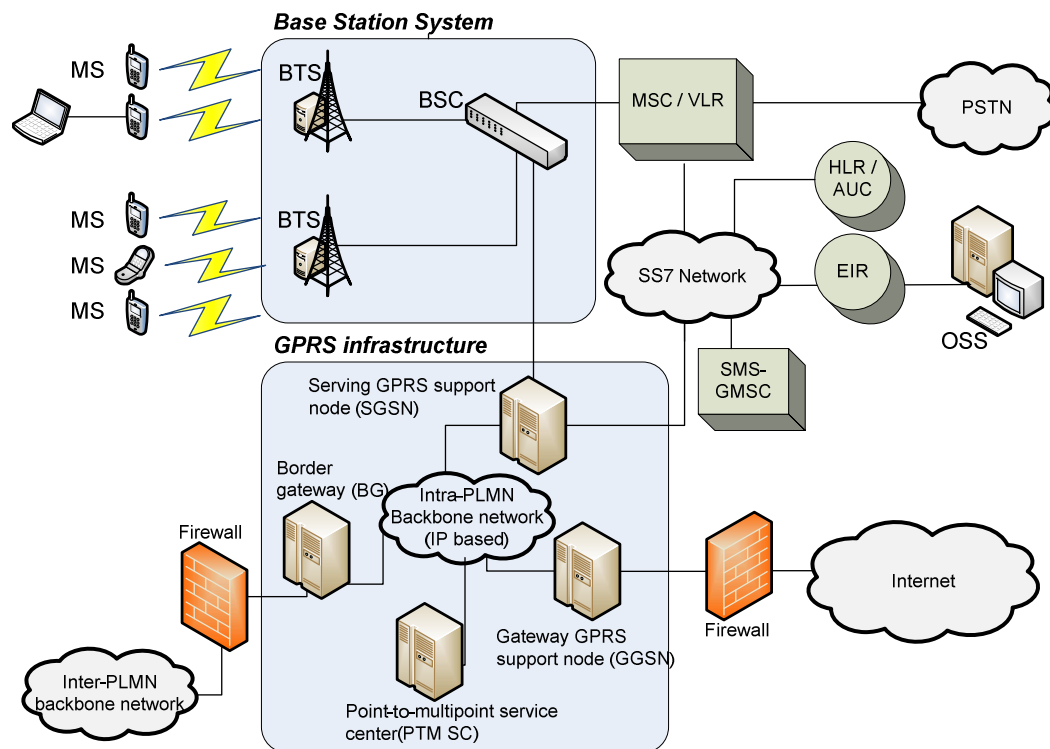


Figure 3. Functional view of GPRS system /1/.

The main component of the GPRS network, the SGSN, operates the mobility management and the authentication process together with some other tasks. It is connected to the BSC and acts as a service access point between the GPRS network and the MS. When authentication of the MS is successful, the registration to the GPRS network and to the mobility management is handled by the SGSN. It also processes necessary protocol conversions between the backbone-network and the sub-network dependent convergence protocol (SNDCCP). /1/

The GGSN is basically a router connecting the GPRS network to external networks. GPRS network remains hidden behind GGSN and is seen as a sub-network by the external networks. /1/

The PTM-SC handles point-to-multipoint services in the GPRS network. With it, the radio traffic can be broadcasted from one source to multiple receiving antennas. /1/



GPRS security is based on the original GSM requirements. The authentication process is controlled by the SGSN. The identity of the user is kept confidential with temporary logical link identity (TLLI). The connection between the international mobile subscriber identity (IMSI) and TLLI is not visible to others except the MS and the SGSN. The incoming and outgoing data between the MS and the GPRS network are protected with optimized ciphering functions for obtaining best results in packet-switched data transfers. /1/

#### 2.2.4 EDGE

Enhanced data-rates for GSM evolution (EDGE) is an improvement to GSM data-rates. With it, the data-rate of the GPRS can be significantly improved. The idea is to improve the throughput of used time-slots. When applied, HSCSD is called ECSD (enhanced circuit-switched data) and GPRS is called EGPRS (enhanced general packet radio service). /1/

In order to gain higher throughput, an 8-PSK modulation (octagonal phase shift keying) is used together with the Gaussian minimum-shift keying (GMSK). In principle, the 8-PSK signal can carry 3 bits for each modulated symbol whereas a GMSK signal can carry 1 bit per symbol over the radio path. The increase in throughput has some implications as the sensitivity of the 8-PSK signal decreases. This has to be considered in the radio network planning. The highest data-rates can be provided only in best circumstances. /1/

When compared to the normal GPRS, the EGPRS is very similar as it is implemented as an add-on to the existing GPRS network. There are only minor changes made to the protocols and the protocol layers. The EGPRS has one bigger extension which is the link quality control (LQC). Within the LQC there are nine modulation and coding schemes (MCS-1 – MCS-9) and some signaling procedures. Modulation- and coding-schemes are used to improve the data throughput and robustness under varying channel conditions. The peak throughput for the EGPRS is tripled from that of GPRS. It is 473 kbps when eight time-slots are used in the radio interface. /1/

Like the EGPRS, the ECSD uses its predecessor HSCSD as a basis. When the ECSD is used, the data-rates are not enhanced when compared to the HSCSD and are still 64 kbps. Instead, the benefit is that same rates can be achieved with fewer time-slots and the implementation is simpler for the MS. /1/

## 2.3 UMTS

The Universal Mobile Telecommunications System (UMTS) is a multi-radio network combining two existing 3G network technologies, GSM/EDGE and WCDMA. One of the main purposes of UMTS is to enhance the services offered for the users of the mobile networks. The traffic type being voice, video, or data, the utilization of universal and fast networks offers clear benefits for both the end-user and the service provider. As specification and development continues, new products and services can be offered for both consumer- and business use. Services with high bandwidth or low latency requirements benefit the most from the new technological advances offered by UMTS. UMTS is standardized by the 3GPP. /1/

### 2.3.1 Infrastructure

UMTS has a new network architecture which is designed to allow flexible implementation of future technologies on top of the existing network infrastructure. When first launched, UMTS brought some larger changes to the existing networks. The radio access network (RAN) was to support the code division multiple access (CDMA) for the air interface and asynchronous transfer mode (ATM) in the transmission part. Software updates were deployed for the rest of the core network components. As radio network controller (RNC) was now transferring using IP, UMTS became a step closer for being a true all-IP network. /5/

3GPP specification refers to the base station as a Node B. Node B is a network entity serving a single cell. In sectorized sites it is still expected to support multiple cells across the full spectrum of the required operating frequency. Node B is commonly referred to as WBTS or BTS. BTS notation is used throughout this document. /5/

After its appearance, UMTS has been developed further in subsequent releases. Changes and improvements have made the system more scalable and after removing old switching solutions from the system, UMTS became an all-IP network. Now the whole system operates on IP protocol and supports a vast variety of services previously not available because of the restrictions set by the old mobile telephone network. /4/

Latest specification is from the year 2007 when Release 7 was published. Along with other improvements, the data transfer speed for high-speed packet access (HSDPA) was upgraded. UMTS is now very near to a point where it can truly enable any person-to-person services, content-to-person services, and business connectivity previously available only with personal computers. /5/

### 2.3.2 WCDMA

In normal GSM transmission only one user is transmitting and the others are waiting for the time-slot to become available. In WCDMA system all users transmit at the same time and at the same frequency which improves the use of resources. The technique is called code division multiple access (CDMA). It uses a signal-spreading technique for the expansion of the signal frequency spectrum. It also decreases the overall power level. In WCDMA systems the power level of transmission is reduced by wide banding the signal frequency in this fashion. With the same procedure performed to other transmitted signals, the total system power is still increased as all signals are transmitted at the same time. Each new user increases the power of the wideband signal. The signal spreading principle is presented in Figure 4. In WCDMA systems the signal is spread over the 5 MHz frequency band. /5/

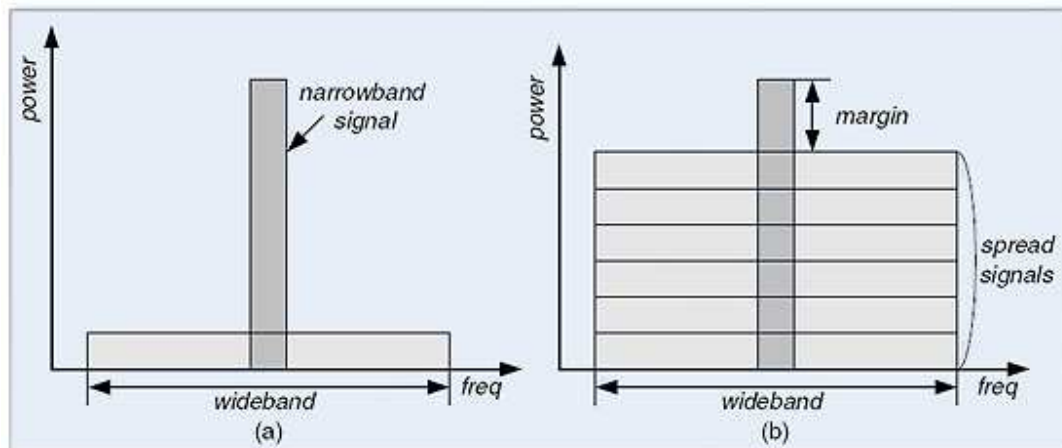


Figure 4. Signal spreading /5/.

WCDMA defines the service capabilities for different terminal classes. The network receives information on the radio access capabilities of a single terminal. From these parameters the supported data-rate can be determined and used for allocating resources for the terminal. The classes are divided by speed and supported telephone operations. The 32 kbps class is for speech services, the 64 kbps class is for speech and data services. The 384 kbps class has a multicode capability and it is aimed for meeting the packet-data requirements of WCDMA. Though not actually implemented, the 2 Mbps class is defined only for downlink data transfer purposes. /5/

UMTS has three-layer hierarchy at the UE. A logical channel is dedicated for transferring information over the radio interface. A transport channel handles the transport of logical channels between the UE and the RNC. The air interface is a physical channel defined by the WCDMA code and frequency. The layer model used in UMTS is shown in Figure 5.

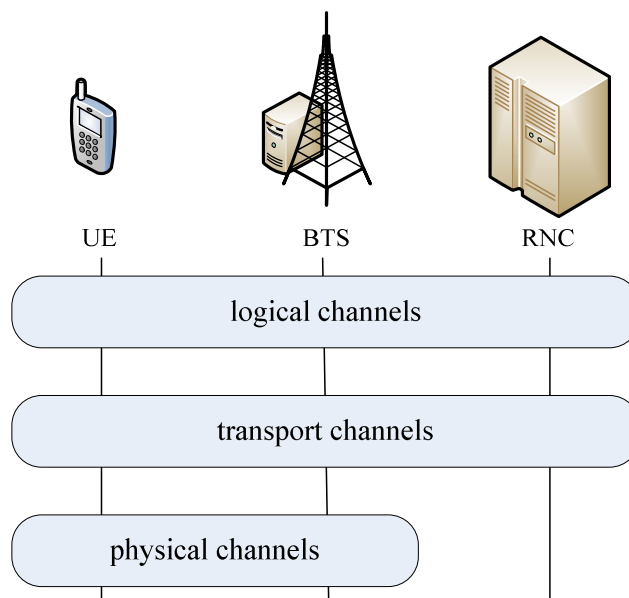


Figure 5. UMTS channel structure /5/.

WCDMA has three transport channels for downlink packet-data transfers; the dedicated channel (DCH), the downlink-shared channel (DSCH), and the forward access channel (FACH). The random access channel (RACH) is a FACH equivalent in the uplink. These are specified in the Release 4 of the WCDMA specification. /5/

The DCH transports service data (such as speech frames) and higher layer information (such as hand-over commands) when the UE moves to another cell and the BTS is changed. It can also be used to transfer network measurement reports. /5/

The DSCH is used for carrying dedicated user data and control information where applicable. The DSCH supports fast power control and variable bit-rates. /5/

As a downlink transport channel, the FACH carries control information to UEs located in the cell. Packet-data can also be transferred on the FACH. If more than one FACH is used in one cell, higher data-rates can be used for the additional channels. /5/

### 2.3.3 HSPA

The high-speed packet access (HSPA) is an upgrade to the WCDMA network. It offers high-speed network access with significant increases in the data transfer speeds when compared to the standard WCDMA packet-switched data. For downlink, there is the high-speed downlink packet access (HSDPA) and for the uplink the high-speed uplink packet access (HSUPA). Both have been specified separately in order to overcome the technical limitations and prerequisites like the signal power when sending data with HSUPA. /5, 6/

Being a part of the UMTS, the HSPA is also specified by the 3GPP. In 1990s, the International Telegraphic Union (ITU) originally planned for a 2 Mbps bit-rate requirement for the IMT-2000 systems. Even though the specification for the WCDMA supports 2 Mbps, the implementation does not achieve speeds over 384 kbps. The HSDPA can offer speeds up to 2 Mbps and will likely exceed 10 Mbps in the future when new specifications are released. The different HSDPA- and HSUPA- categories are shown in Figure 6. /5, 6/

HS-DSCH Category	Max number of HSDSCH codes (SF16) received	Modulation	Max peak rate (Mbps)
Category 1	5	QPSK & 16-QAM	1,2
Category 2	5	QPSK & 16-QAM	1,2
Category 3	5	QPSK & 16-QAM	1,8
Category 4	5	QPSK & 16-QAM	1,8
Category 5	5	QPSK & 16-QAM	3,6
Category 6	5	QPSK & 16-QAM	3,6
Category 7	10	QPSK & 16-QAM	7,3
Category 8	10	QPSK & 16-QAM	7,3
Category 9	15	QPSK & 16-QAM	10,2
Category 10	15	QPSK & 16-QAM	14,4
Category 11	5	QPSK only	0,9
Category 12	5	QPSK only	1,8

Figure 6. HSDPA categories /7/.

The HSPA also has other benefits like the reduced latency and improved network capacity. The latency and speed comparison for other data transfer technologies is presented in Figure 7. /6/

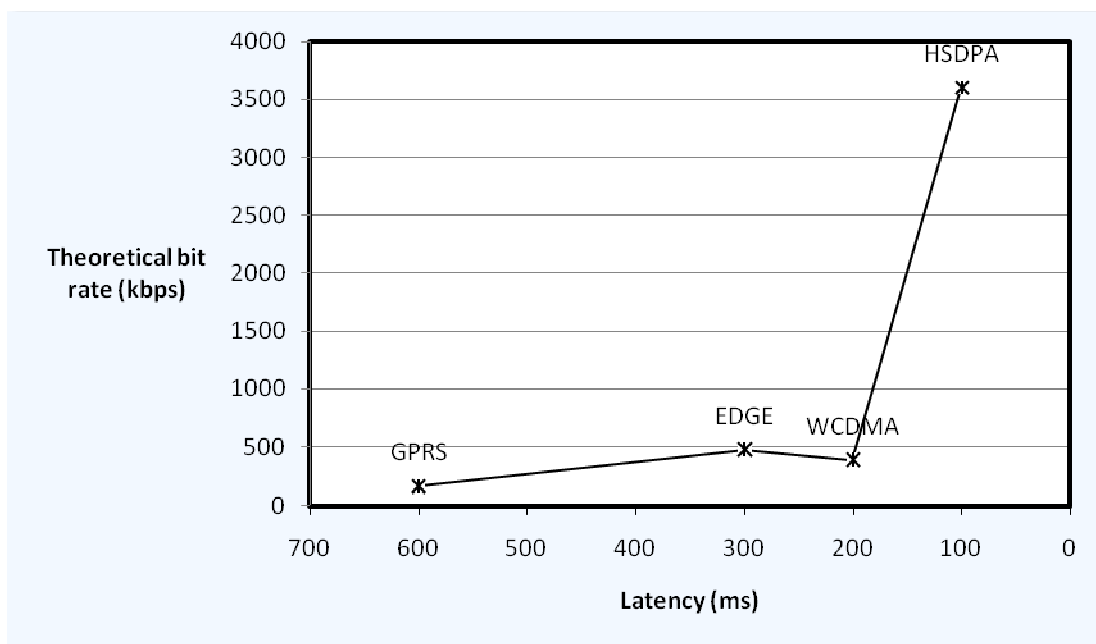


Figure 7. The latency and speed chart. /6/

The improved radio capabilities make it possible to offer new packet-based applications in an efficient way. For the network operators the HSPA is an inexpensive solution as it completely reuses the existing network elements and only needs minor additions and software upgrades. /6/

For increased packet-data throughput, the HSDPA has been designed with a fast physical layer transmission and retransmission together with a fast link-adaptation controlled by the BTS. Based on the physical layer feedback the BTS estimates the channel quality for all active HSDPA users. The used scheduling algorithm and the user prioritization scheme determine the used scheduling and the link-adaptation conducted to the user. In case of a packet decoding failure, the BTS can retransmit the data from a buffer where it was first received. Retransmissions are automatic and do not involve the RNC. /6/

The high-speed DSCH (HS-DSCH) has a key part in the HSDPA data transfer. It is a transport channel carrying the actual user data being transmitted with the HSDPA. The needed channels for HSDPA operation are presented in Figure 8. The HS-DSCH has some major differences when compared to the earlier specifications with the DCH-based packet-data operations. There is no fast power control, no soft hand-

over, no physical layer control information, and no discontinuous transmission (DTX) on the slot level. As add-ons, there are some big improvements. There is a support for higher order modulation as the HS-DSCH uses 16-quadrature amplitude modulation (16QAM), effectively doubling the number of bits carried per symbol under good conditions. With the fast physical layer signaling the user allocation with the BTS is done every 2 ms. Turbo-coding is used for the HSDPA but DCH can still be used if necessary. /6/

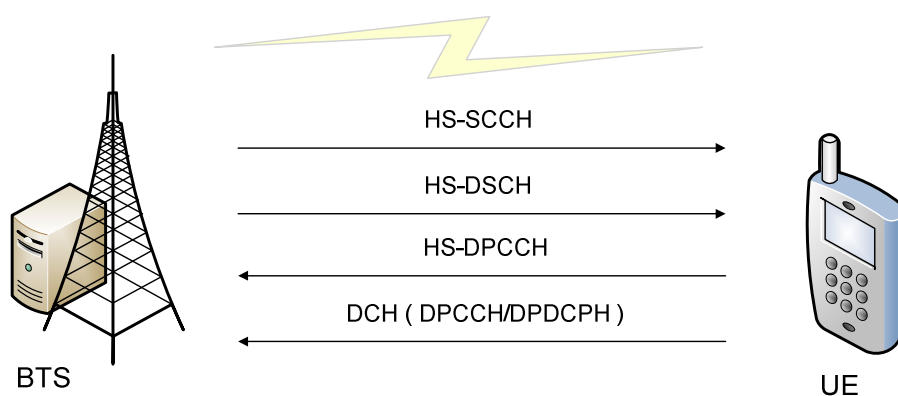


Figure 8. Transport channels needed for HSDPA operation. /6/

The short 2 ms allocation time enables the dynamic resource sharing of the HS-DSCH. If the UE does not need a high-speed data throughput for a while, the code resource reservation is not changed to a lower bit-rate. Instead, no data is transmitted with the high-speed physical downlink shared channel (HS-PDSCH) where the HS-DSCH is mapped. The previously used resource for the 2 ms slot can then be allocated for another user. /6/

The high-speed shared control channel (HS-SCCH) carries time-critical signaling information allowing the terminal to demodulate the correct codes. If time multiplexing is used, only one user receives data at a time. If code multiplexing is used, more than one HS-SCCH can be used. The data-rate available for users is still dependent on power allocation, environment, and the type of the used terminal. /6/



The high-speed dedicated physical control channel (HS-DPCCH) is used to enable the link-adaptation and the physical layer retransmissions. As the signaling is handled on a parallel code channel, the DCH operation remains unchanged. The feedback information carried on the HS-DPCCH informs the BTS if the packet was decoded successfully. The channel quality information (CQI) tells the BTS scheduler the data-rate which UE expects to be able to receive. /6/

The enhanced uplink dedicated channel (E-DCH) is a completely new uplink transport channel for HSUPA. While bringing in some same features that HSDPA has in use, the E-DCH offers dedicated data path to the BTS for each UE. New signaling channels are also introduced for HSUPA and can be seen in Figure 9. In theory the maximum physical throughput for HSUPA is 5.5 Mbps. /6/

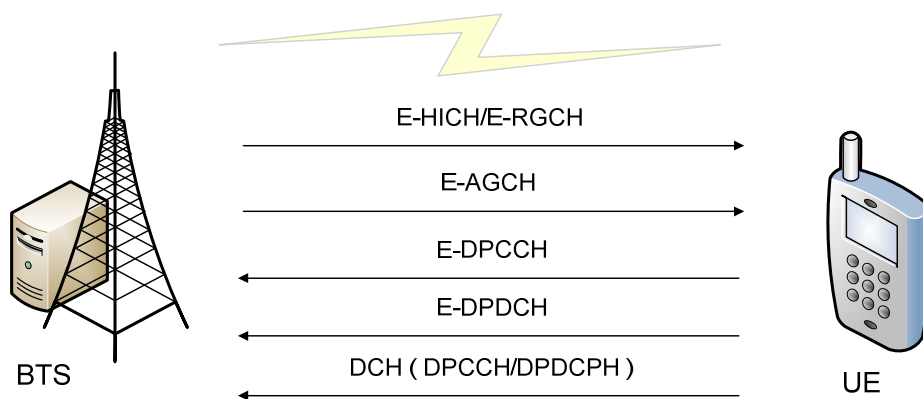


Figure 9. Transport channels needed for HSUPA operation. /6/

The E-DCH absolute grant channel (E-AGCH) and the E-DCH relative grant channel (E-RGCH) are used for scheduling control together with the EDCH HARQ indicator channel (E-HICH) which offers retransmission support. The enhanced dedicated physical data channel (E-DPDCH) is used for carrying the user data while the control information is transmitted on the E-DCH dedicated physical control channel (E-DPCCH). /6/

The end-user performance of the HSPA depends on many different factors. The performance depends on deployment and service parameters and varies depending on the use-case scenario. The most significant factors affecting performance are the used network algorithms, deployment scenario, and mobile station performance and

capability. In field experiments there are many variations to be considered. The amount of HSDPA users sharing the common HS-DSCH per each cell has a definite effect, and the throughput decreases as more users are allocated for the same channel. Estimation of bit-rate differences between dedicated or shared carrier can be seen in Figure 10. Throughput in a HSPA system will also be affected by the physical environment itself in the form of tall buildings, closed spaces, or UE movement, for example. It has to be noted that many applications benefit from the low latency and not necessarily from the high data throughput. For this purpose the round trip time of a small packet can be measured. /6/

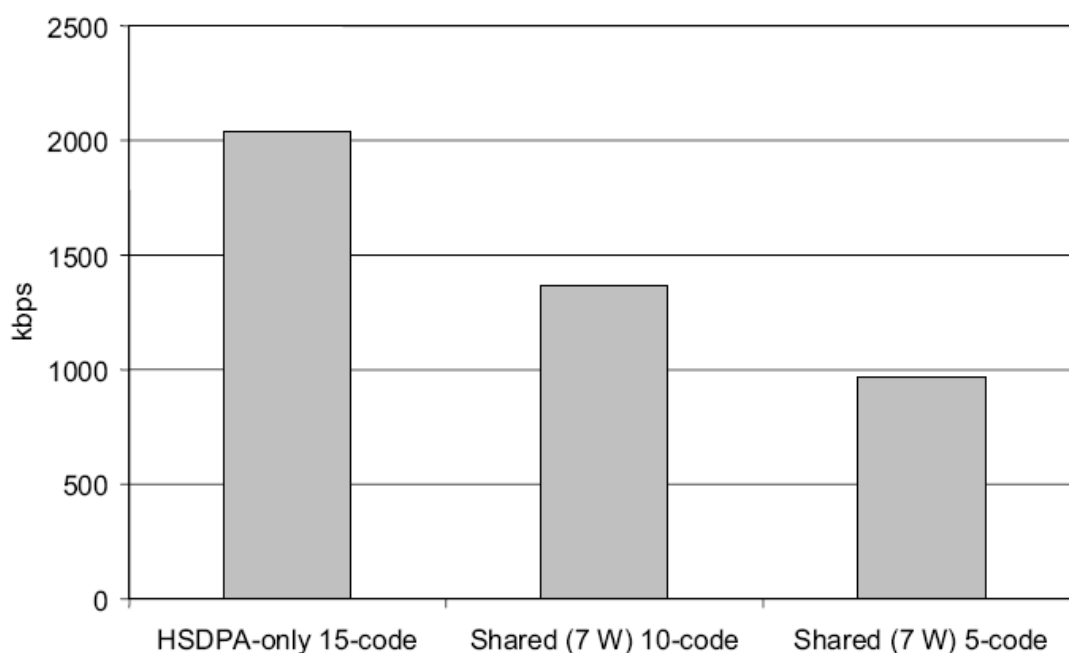


Figure 10. Average HSDPA bit-rates using dedicated HSDPA carrier or shared carrier. /6/

Already the 3GPP framework allows the use of different enhancements for increasing the capacity and the service performance. The advanced receivers are able to obtain a higher signal-to-interference-plus-noise ratio (SINR) allowing higher bit-rates and cell capabilities. These devices will automatically report higher channel quality information (CQI) values and higher bit-rates will be automatically allocated by the BTS scheduler. /6/

## 2.4 Smart Phone

In many aspects the mobile devices have gone through a fast evolution over the past twenty years. A simple phone has evolved to an all-in-one device where the speech services are only one, though important, service. /8, 9, 10/

### 2.4.1 Technical requirements

For taking the advantage of the modern data transfer technologies the phone has to meet three main prerequisites. At the very basic level the phone has to be able to handle the signaling over the air in an efficient and reliable way. Commonly used lithium-ion battery is still a limiting factor and has to be considered when new network technologies are standardized and implemented. /8, 9, 10/

The phone also has to meet the requirements set by the specifications for different wireless technologies. The modulation and coding schemes vary depending on the chosen solution. Telecommunication corporations like Nokia take part in the specification work itself. /8, 9, 10/

The transition from the hardware layer to the software layer on the phone has to be efficient so that the advertised data transfer speeds are attainable in used applications. /8, 9, 10/

### 2.4.2 Symbian platform

The Symbian OS platform is commonly used in today's smart phones by different manufacturers. It has specifically been designed for smart phones where the low power consumption is essential. It uses an object-oriented approach inherited from the EPOC, from which the Symbian OS has evolved from. Symbian is a multitasking and multithreaded operating system where processes can be run concurrently. It has a microkernel design meaning that servers are used to make executive calls into the kernel when needed. The communication-specific architecture shown in Figure 11

shows the client/server structure and the different layers from the application to the device driver. /8/

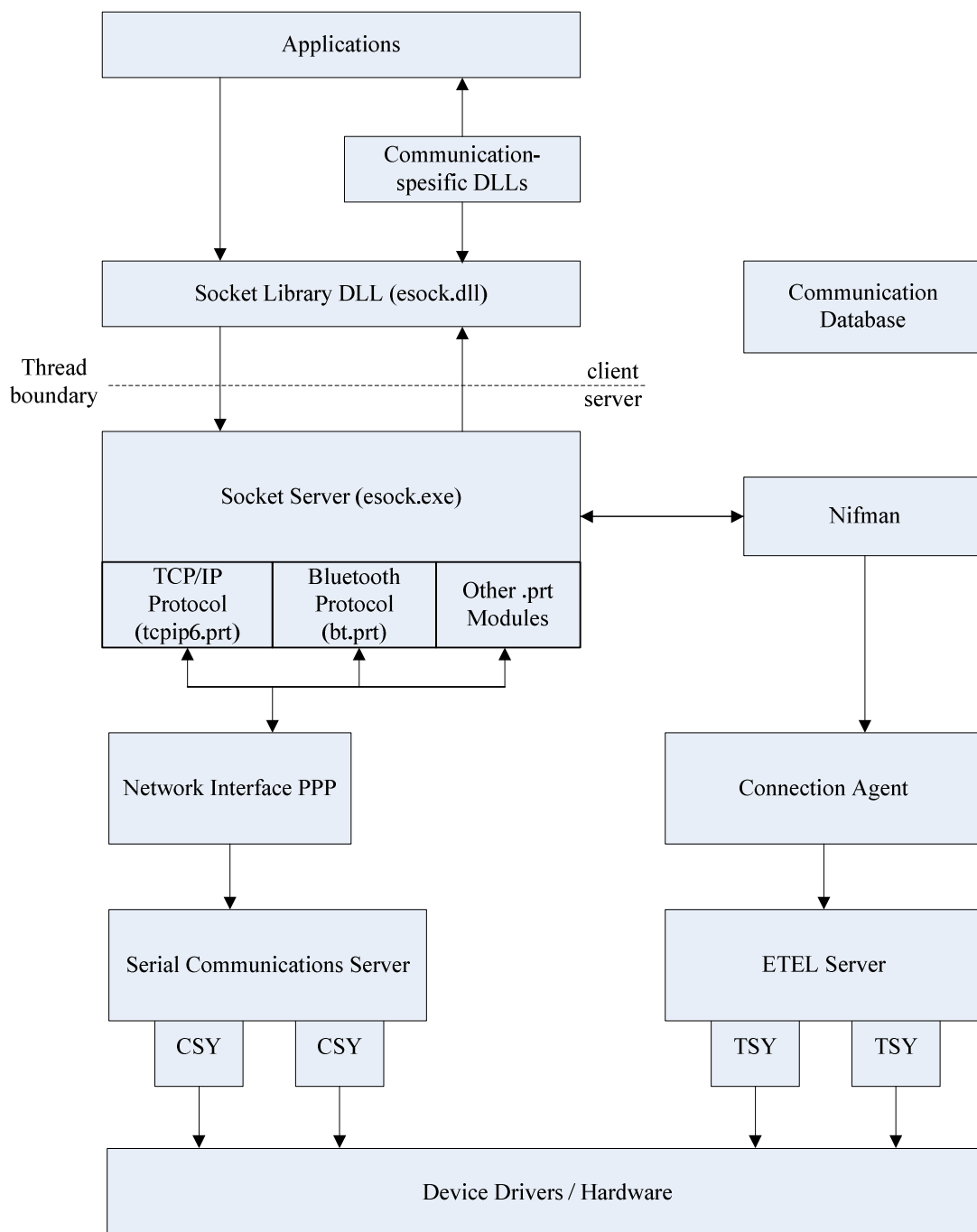


Figure 11. A schematic diagram of the S60 communication architecture /11/.

Virtual machines are also supported in the Symbian OS. The Java programming language and run-time environment use this mechanism. Symbian is also easily extended when new protocol implementations or device drivers are needed. The

microkernel design allows the dynamic loading of new modules. The target devices usually have a 32-bit ARM processor. /8/

### 3 SOFTWARE TESTING

#### 3.1 Reason and benefit

Even carefully programmed software usually has flaws and no such thing as bug free software exist. Mistakes are made in all different stages of software development. /12/

Software testing can be done differently depending on the project goals, available time and resources, and other factors. Usually testing is done because of the need to improve the quality by finding and fixing flaws in the implementation, evaluating if it follows the specification, and for making sure it is compatible with the systems it interacts with. From the managerial point of view it can be done to prevent the delivery of immature software, to evaluate the quality of the software, or to minimize the need for technical support. /12/

#### 3.2 Testing process

The V –model is the most known testing process. The V -model is not often used as it is in modern software development process. However, the newer models are still based on the same concept. The V -model is presented in Figure 12. /12/

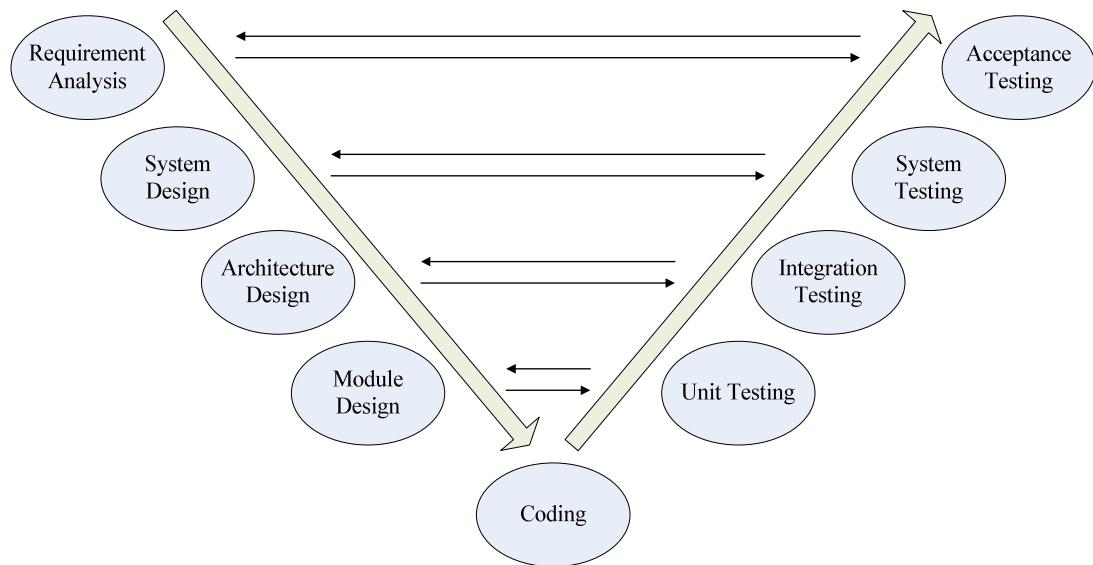


Figure 12. V-model -based testing process. /12/

The left side of the V-model is based on the waterfall model of software development. Requirement analysis is done first, followed by other design steps. At the same time with each design step the test plan for a matching test phase is done. Implementation can be started when all design phases have been finished. The actual testing begins when the material for testing first becomes available. Starting from the unit testing, each phase is done according to previously created test plans. Within each phase testers will verify that the implementation matches the specification. /12/

Testing in the lower levels of the V –model is often glass box testing where the test engineers have access to the actual implementation. On the higher levels the testing is more often black box testing where the implementation is not visible to the testers. /12/

Traceability between different testing phases helps in resolving the origin of the found errors. When an error is located, the testing process can be adjusted so that similar errors will be found sooner. /12/

### 3.3 Testing methods

When unit-testing is being done, each unit of the program is tested separately. A unit can be a module, class or a process. Unit testing is usually part of the implementation phase as the programmer will check his/her own implementation. Knowledge of the errors usually remains with the owner of the code. The sooner the unit testing is done the better. /12/

Unit testing is usually glass-box testing but also some black-box testing methods can be applied. The categories of unit testing are:

- API's
- data structures
- paths and loops
- error handling
- limiting values

Having been tested, the units are integrated into larger entities. API's and their co-operation are tested during integration testing. Test automation and smoke testing should be applied to this process if possible. Integration testing can be thought of as an implicit part of the unit testing, especially if the software is small in size and the units are integrated incrementally. In good software architecture every unit handles its limited mission as independently as possible because the unnecessary dependencies between units make the maintenance more difficult. /12/

System testing is done for testing the functionality of the newly build system. System testing is usually operated by a separate testing team. Fixing the errors found in system testing is usually expensive as the correction can have an impact in the architecture or in the module design. It is possible that large parts of the system will need to be re-tested. System testing takes the longest time of all testing phases. Running all of the test cases can take a lot of resources. /12/

Acceptance testing is done for a product which is ready to be delivered. Acceptance testing is based on the customer requirements. When finished, it can be determined if

the software is done according to the contract. Because the acceptance testing is done with the final product, the end-users can be used as testers. The used test-environment needs to be as close to the real-life environment as possible. Acceptance testing does not usually last long as the meaning of it is to verify that the requirements have been met. /12/

Acceptance testing should mostly be a demonstration of the software. There is a high likelihood for errors to be found if the end-users get to use the software just when it is supposed to be ready. /12/

### 3.4 Quality assurance and continuous development

Quality assurance generally has three major components:

- software testing
- quality control
- software configuration management

Software testing is a continuous process done in parallel with the software development. The purpose is to verify and validate the changes made and so ensure that the software design, code and the documentation meet the given requirements. It is focused on the test planning, test design, test development, and test execution. /13/

Quality control is an important part of quality assurance. It comprises of the processes and methods used for monitoring the work and observing how the requirements are met. Structured walkthroughs and inspections are used for removing the found defects during the software development. /13/

Defects can also be fixed with the help of technical reviews done during the development life cycle. The idea behind the technical reviews, or “peer reviews”, is to increase the efficiency of the development life cycle and to provide methods for measuring the quality of the product. These reviews are one form of testing which does not involve program execution or a computer. Usually technical reviews



remove bugs or defects early in the development process and so save the resources otherwise needed to find and repair the issues later. /13/

The quality of testing can also be improved by investing to the personnel. The know-how can be increased in seminars or trainings. /13/

## 4 TESTING DATA TRANSFER IN A MOBILE NETWORK

For running tests with different data transfer technologies a cellular network supporting GSM and WCDMA is needed. Appropriate telecommunication standards and specifications will have to be supported by the used network for assuring the interoperability between the UE and the cellular network. These conditions can be met by using a commercial cellular network or a radio communications tester.

### 4.1 Test automation

In order to thoroughly test the implementation of a given network technology, a fully automated test system is needed. When the test environment, test modules and other tools have been designed and implemented properly, a fast, reliable, and customizable way for running the tests is established. With a functioning test automation system different types of test cases can be implemented with ease.

The used system consists of multiple different components and functional entities, enabling large-scale automation in software testing. The dependencies for the network test module can be seen in Figure 13.

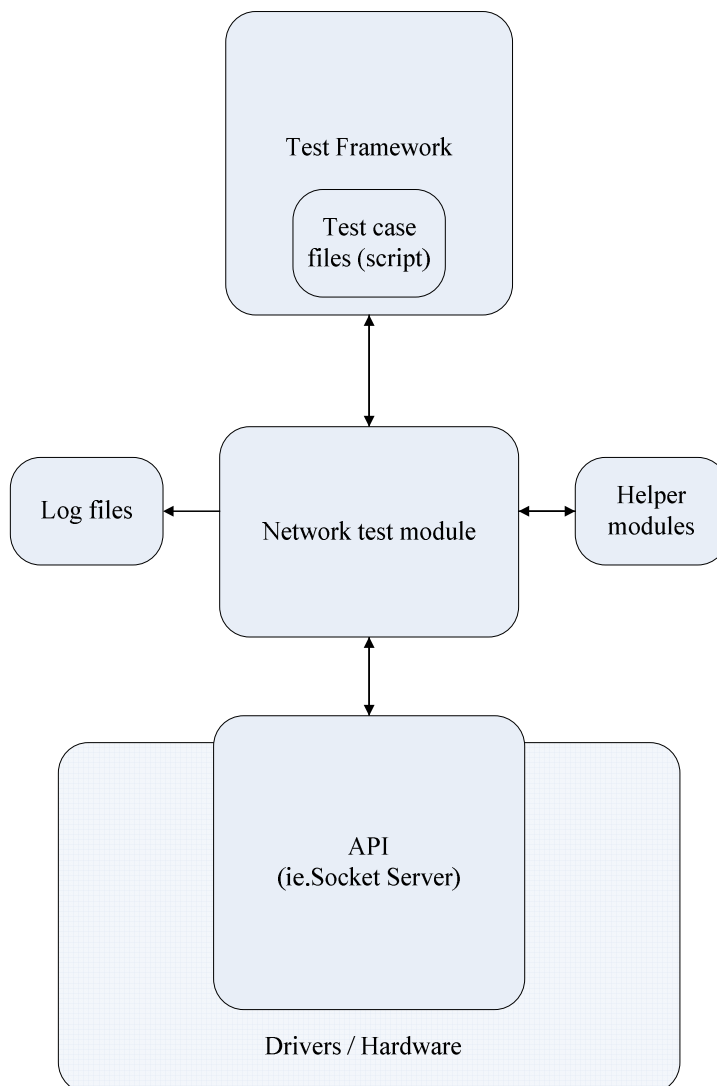


Figure 13. Test module dependencies.

On the lower level the required components are the test module, possible helper modules, and access to the correct API's enabling the needed functionality.

The test automation makes the test engineers' job easier and the test developer can concentrate on developing quality test asset for the target platform or technology.

#### 4.2 Functional testing

When the data transfer technologies are tested, one of the main objectives is to verify the basic functionality of a given property. Besides error reports, test run results can be used for creating metrics for keeping track with the development progress.

Functional test cases for the different network technologies are ran between different development cycles for verification purposes.

Functional test cases will have to cover the target technology as thoroughly as possible. This can be achieved by targeting the test set to match the specification and by covering the components and API's. Overall the aim should be at making the most of the used technology, whether it is GPRS, EDGE or HSPA. Functional testing ensures that both the hardware and the software implementations work as specified and that the mobile phone can be used in normal operating circumstances in different ways.

#### 4.3 Non-functional testing

Non-functional testing concentrates on finding unwanted behavior in most common use-cases. Non-functional test cases for network technologies can be categorized into different groups based on the scope of the tests:

- long-lasting
- feature interaction
- stress
- throughput
- negative tests

Long lasting test cases test how the feature behaves when used continuously for a long time, possibly for hours or days. Failures in these cases could be caused by many different factors, memory leaks for example. Feature interaction test cases are used to test how different features work when used at the same time with some other functionality. Throughput test cases calculate the data throughput for different data transfer technologies. Results can be used for verifying that the specified data transfer speeds are attainable. Negative test cases are used for testing how the platform recovers from situations where the API's are used with values or ways not intended. Problems in error handling or recovery could potentially cause instability of the system, or even have effect in platform security.

HSDPA and HSUPA have different speed classes which are based on the 3GPP specification versions. This has to be considered when throughput testing is done for different software platforms with support for different categories. Correct target values will have to be used for getting proper results for data throughput. Support for higher data transfer speeds is currently only available in radio communications testers.

#### 4.4 Review of existing test methods, test cases, and documentation

Sahti's specification, test mass, and documentation were reviewed as part of the work done for this thesis. As Sahti had been implemented in the past, the aim of the review was at finding:

- missing test cases
- duplicate test cases
- un-used test cases
- errors/problems in the test cases or in the test module
- documentation improvement needs

Results for the review were reported and action points created so that correct actions could be taken. These action-points were later implemented to the test module as new functionality or new test cases.

Sahti's test cases and functionality are business secrets. Because of this, detailed information about the test cases, functionality, or test environment will not be presented in this thesis.

#### 4.5 New test methods and test cases

New functionality and test cases were implemented based on the module review and other received requirements. Test sets were modified to remove duplicate and un-used test cases.

#### 4.5.1 Information gathering

Requirements for new test cases are received from multiple different sources. The test engineer can implicate a problem or area that has not been fully covered, errors can have been found in verification or later stages of testing process. Problematic areas can be also pointed out by other persons involved in development or testing process.

The responsible test developer should have the will and competence to break borders with new ideas for test cases and new solutions.

#### 4.5.2 Test case design

After the need for a new test case or functionality has been found, the basic design plan can be done. It is usually done by using a template designed for this purpose. The used platform, hardware, and the test module are specified together with the desired output. The test case design is used as a primary guideline when new test cases are being implemented.

#### 4.5.3 Test case review

The proposed test cases or functional entities are reviewed before the implementation phase. This is for ensuring that they are required, feasible, and that they can be implemented. The review can be done via email or by arranging a teleconference. Apart from the test developer, the participants can be the software integrators, test engineers or other people involved.

#### 4.5.4 Test case implementation

Two common ways for creating new test cases exists. The first requires that both the new code and the test script are implemented and released for testing. Alternatively, if the test case does not require new functionality from the test module, it is usually implemented simply by modifying the test script accordingly.

Only a script modification was needed when Sahti needed a new test case which would download a file to eMMC (Embedded MMC) drive with HSDPA connection. eMMC is an embedded mass memory integrated to some smart phones. The new test case was implemented simply by modifying an existing test case used for downloading a file to a memory card. The download function uses HTTP-protocol for receiving the file from the specified Internet address. As the downloading functionality already existed, the implementation required only a change in the drive letter used for saving files. This test case verifies that a file download to the eMMC drive works when HSDPA is used.

Either it being a new test case or functionality, the implementation has to be verified working before it can be released for testing. It is done by running the smoke test sets which utilize the newly-implemented code on different software platforms. Failed test runs will point out the possible bugs and build problems. This prevents the delivery of faulty test software.

#### 4.5.5 What's new

Sahti's code was inspected with CodeScanner, a static code analyzer which checks that common rules and programming practices are being followed. No critical errors were found from Sahti but some minor corrections were made based on the findings.

Sahti's logging methods were improved based on test engineers' requests. Progress information was needed for long lasting test cases. This feature would allow the test engineer to track the progress when the test case has been running for some time. The new implementation gives progress information based on the pre-set duration of the test case.

Throughput test cases were and are being improved as the test environment is under development. Throughput testing will be done with a radio communications tester for ensuring stable testing environment. Throughput test cases were inspected and plans

were created to continue the development. At this point changes were only made to the test case durations.

New feature interaction test cases were needed for testing how the UE behaves when data transfers technologies are used at the same time with some other UE functionality. Test cases using GSM EDGE, WCDMA packet-switched data, and the HSDPA connection concurrently with WLAN (Wireless Local Area Network) were created. The test case is implemented so that it downloads data simultaneously with both features under testing. WLAN test module was used to enable the functionality needed on the WLAN side.

The biggest single improvement made for the Sahti test module is HSDPA/HSUPA disable/enable -function. The request for the new functionality came from the test engineers, who had to disable the HSPA manually with separate software. It had to be done before running the test cases where HSPA was not meant to be available. The UE uses the best connection method available by default. A study done before the actual implementation implicated that the functionality could be added to Sahti in a feasible way.

The implementation allows scripter level definition for HSPA usage. Low level system messages are used to disable or enable both HSDPA and HSUPA. The implementation first creates and sends a message for changing the correct bit. Response message is read for verifying that the first message was received correctly. Second message is send for actually saving the new setting on the UE. Received response message again verifies that the operation was successful. In case the function fails to change the setting an error code is returned. Before the test case finishes, Sahti also checks if HSPA is required and if it was in use. All Sahti's test cases utilizing WCDMA now use the functionality.

## 5 THE NEW TEST MASS IN USE

### 5.1 Evaluation, efficiency and coverage

The new test set for the Sahti network test module includes the modified test cases, in addition to some completely new ones. Test cases were created and removed based on suggestions, propositions and requirements received from the people involved in the testing process.

The efficiency of the improved test asset cannot be measured reliably as the test cases and platforms are tested in different locations and by different people, and also with other test software. There are no metrics available on how the network test cases perform; usually errors are found, tracked and fixed independently invisibly to the test developer. Found errors or bugs are not usually reported back to the test developer. However, the time needed for running all of the test cases is now shorter as the test asset was streamlined and some long lasting test cases were removed as duplicates. The implementation of the new functionality disabling or enabling the HSDPA/HSUPA speeds up the testing process by removing the need for manual configuration.

Network testing is a continuous process and in its part guarantees the quality and the functionality of the end product.

### 5.2 Future technologies and development needs

The network test development continues as new network technologies and software platforms are to be introduced to the market. The data throughput speeds for HSPA will increase as the specification process reaches gets to next releases. Category 10 HSDPA will offer 14.4 Mbits/s peak data throughput rate whereas the category 6 HSUPA will offer 5.76 Mbit/s data throughput. How these are implemented, tested and used in tomorrow's smart phones remains to be seen. Regardless, the HSPA will be under heavy testing in the future too.



Sahti also has other development need for the future. Currently only basic networking is thoroughly tested. Test cases utilizing UDP (User Datagram Protocol) as data transfer protocol could possibly be implemented. UDP is widely used for streaming audio or video in the internet. It might also be useful to have a wider range of feature interaction test cases utilizing Sahti. Internet access is one of the most used features in today's smart phone and is likely active during many other operations.

Laboratory environment and network tester could be used in more large scale in the future. More complex test cases could be created for that purpose as the network testers can be configured for different test scenarios. Currently test cases are mostly run against commercial networks which make it impossible to see if the performance or reliability differs in other than optimal circumstances. Testing could be pointed more towards the specifications and seeing how they are met.

Two competing future technologies are also in development; LTE (Long Term Evolution) is part of the 3GPP Release 8 specification and is expected to introduce data transfer speeds up to 100 Mbits/s downlink and 50 Mbits/s uplink. The other new technology is the WiMAX (Worldwide Interoperability for Microwave Access). It is based on the 802.14 standard finished in the year 2001. It has been under development ever since by the WiMAX forum. WiMAX forum consists of over 500 companies all over the world.

The future of wireless networking seems interesting. A very conservative estimation would be that in the future the smart phone owners will see quite broad a spectrum of innovative services making the use of high-speeds and low latencies offered by the rival technologies.

## 6 SUMMARY AND CONCLUSION

The original schedule set for finalizing this thesis was a bit too optimistic as the technological aspects of different network technologies took more time to understand

and to put together than expected. Furthermore, summer holidays and other assignments delayed some parts of the work.

The aim of this thesis was successfully achieved. The test asset is now broader, the test module more flexible and documentation more precise. Overall, the situation seems very good as the absence of leaked errors in this area has shown. It has to be pointed out that the test module was of high quality to begin with and no large-scale refactoring was ever required.

The author of this thesis has benefitted greatly from working in this area, both in terms of competence and job motivation. The background work for the thesis was the most demanding task. In order to understand the functionality of newer technologies like HSPA, one has to understand, at least to some degree, how the GSM- and WCDMA -based networks work. Understanding the big picture of modern cellular networks is an advantage in many ways. Test development in this area is now easier, more encouraging, and hopefully more beneficial in terms of the quality of the test asset.

Working in the networking area has revealed a complex technology lying behind the simple icon named the Internet in today's smart phones. The network technologies are in constant development and will continue to offer challenges and surprises for the future test developers.

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