Information Theory and Signal Processing in GSM Network

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***Abstract*— In this paper we suggest a new presentation and overview of telecommunication networks or GSM network. It is a great opportunity for me to manipulate and do to many actions inside the GSM network that equip with hundred electronic systems like: Mobile Station (MS), Base Station Controller (BSC), and Base Transceiver Station (BTS), Mobile Switching Center (MSC), Transcoder Rate Adaptation Unit (TRAU),Home location Register (HLR), Service Control Point SCP, Service GPRS Support Node (SGSN), Gateway GPRS support Node(GGSN) , Add Drop Multiplexer(ADM) for SDH transmission. Element Network based on Information theory/Signal processing (ENIS) used in cascade configuration is the key to understand more about methods, architectures, algorithms used in information theory, signal processing and protocols even if the network is complex. The important thing is whatever the equipment in network it can be presented with one or two ENIS, with the specific ENIS we can learn more about many issues hidden for example: source coding/decoding, channel coding/decoding, interleaving /de interleaving, encryption/decryption, modulation /demodulation. But in practice protocols of communication is often apply for trouble shooting and control.**

***Index Terms*—Bits rate, cascade configuration, element network based on information theory/signal processing, protocols.**

I. Introduction

We have been working for ten years in telecommunications equipment; many actions were done like: Installation, supervision, maintenance, extension, quality of service, swapping. The equipment sets constitute a telecommunication network for example: Platform of Internet Service Provider (ISP), Mobile Network Operator and Public Switched Telephone Network (PSTN). The common important concept in all networks is the concept of “Protocols of communication” according to OSI model (7 layers): TCP/IP for ISP network, SS7 Signaling System and LAP-Dm for GSM network (presented in Fig. 1), X25 for Postal check. These networks are installed by the International Telecommunications Companies now it is the time to discover these huge networks, the question is where information theory and signal processing? Element network based on information theory and signal processing (ENIS) is the key of our studies.

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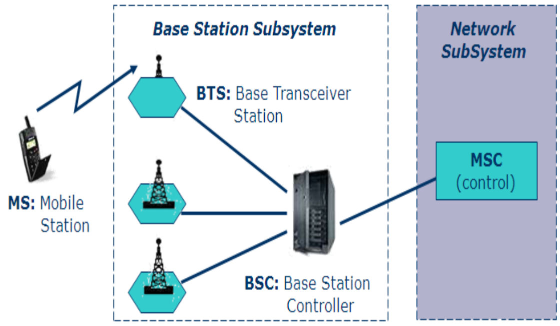

Fig. 1. Equipments’ in GSM network.

II. Element Network Based on Information Theory and Signal Processing

Element Network based on information theory /signal processing (ENIS) represents Equipment of Telecommunication in GSM network like: Mobile Station (MS) by one (ENIS), Base Transceiver Station (BTS) , Base Station Controller (BSC), and Mobile Switching Center (MSC) by two (ENIS) for each one , as shown in Fig. 2.The functions of ENIS are known:

Source Coding /Decoding
- Channel Coding/Decoding
- Interleaving/ De interleaving
- Encryption /Decryption
- Modulation /Demodulation

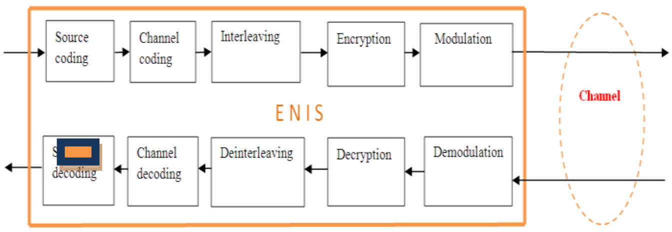

Fig. 2. Element network based on information theory /signal processing.

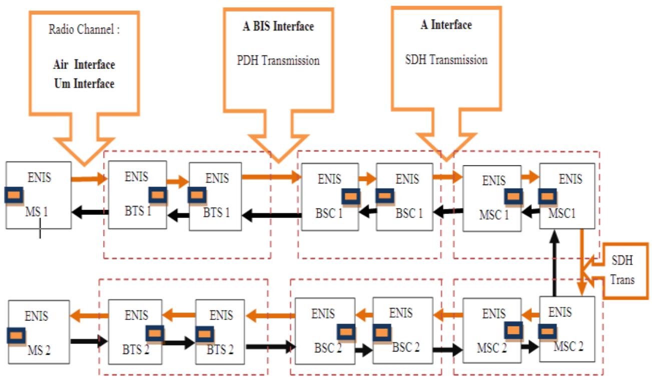

Fig. 3. ENIS in cascade configuration.

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Because if we want transmit information or signal through specific channel to the destination, we use many telecommunications equipment or many ENIS in cascade.

The Fig. 3 shows the cascade configuration of GSM network. The transmission used: PDH (Plesiochronous Digital Hierarchy) for ABIS interface between BTS/ BS. SDH (Synchronous Digital Hierarchy) for A interface between BSC/MSC and between MSC/MSC.

III. Information Theory and Signal Porcessing between MS et BST

A. Source Coding / Decoding

For the voice, to pass an analog-to-digital converter is actually a sampling process in the rate of 8KHz, after quantification each 125µs contains 13bit of code stream we get bit rates 104 Kbit/s (Physical Channel) and then speech coding is performed with every 20ms as a segment and the code transmission rate is reduced to 13Kbit/s (Logical Channel), after using “Regular Pulse Excitation Long Term Prediction “(RPE-LTP-LPC) [1]. The logical channel (TCH/FS) or Traffic channel full rate 13 kbits/s, (TCH/HS) Traffic channel half rate 5.6 Kbits/s , For the data rate we have TCH/F9.6 : Traffic channel full rate data 9.6kbit/s. The physical channel has two logical channel : TCH (Traffic Channel) : for digital voice.

SACCH (Slow Associated Control Channel) :for controle of physical paramter of the link [2].

The organization of logical channels is presented in Fig. 4

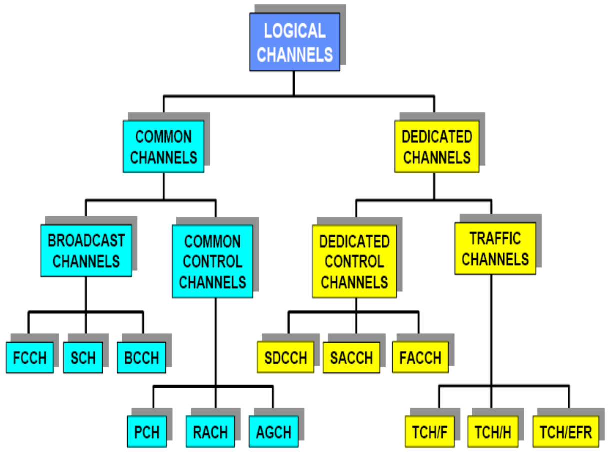

Fig. 4. Principal functions of logical channel

FCCH: Frequency correction channel
SCH: Synchronisation channel
BCCH: Broadcast channel.
PCH: Paging channel
RACH: Random access channel.
AGCH: Access granted channel
SDCCH: Stand associated control channel
SACCH : Slow associated control channel
FACCH: Fast associated control channel

FACCH: handover command (Uplink and Downlink).

BCCH: the GSM mobile measures the cell strength to see if it should change its primary cell (Location update). The signal strength of the broadcast control channel (BCCH) will be monitored to select the best cell (Downlink).

PCH: Paging (Downlink).

RACH: RR Channel request (Uplink).

AGCH: mobile wait for an assignment (Downlink).

SDCCH: Signaling (Uplink and Downlink).

SACCH: when the call is active, the mobile periodically reports the signal quality to the network via the measurement report message. The message is sent in every SACCH frame with a periodicity of 480 ms (Uplink and Downlink).

B. Channel Coding / Decoding

The radio channel is quite different from the wired channel. First, the radio channel has a distinct time-change characteristic. The radio channel is exposed to the air, so it is vulnerable to the interferences in the air. The signal is influenced by various interferences, multi-path fading and shadow fading, so the error bit ratio is rather high**.** To solve the problems mentioned above, a series of forward and backward (uplink & downlink) transmission techniques are applied. The original subscriber data or signaling data are transformed before being carried by the radio waves. And at the other end of the transmission, a reverse transforming will be done. This can provide necessary protection to the transmitting signal. The transformation methods roughly include the channel coding/decoding, interleaving/de-interleaving, burst formatting, encryption/decryption, and modulation/demodulation. The bits rate becomes 22.8Kbit/s after the channel coding; then the voice becomes a code stream at 33.8kbit/s after code interleaving, encryption and burst formatting and is transmitted finally. The processing at the terminal is just the reverse of the above procedures [3]. As describe in Fig. 5 below.

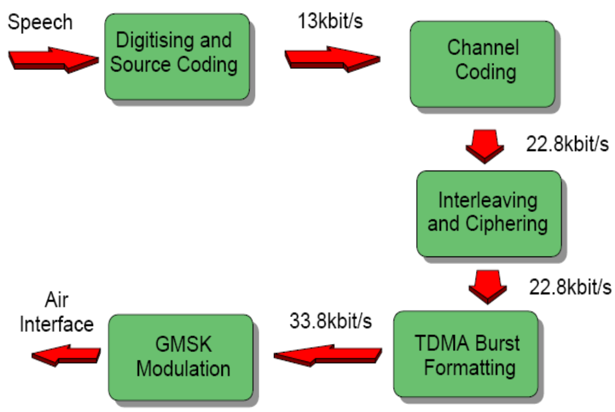

Fig. 5. Bits rate in MS.

Channel coding refers to the class of signal transformation designed to improve communication performance by enabling the transmitted signals to better withstand the effects of various channel impairments. Channel coding can be partitioned into two areas, waveform (or signal design) coding and structured sequences (or structured redundancy.) Waveform coding deals with transforming waveforms into “better waveforms,” to make the detection process less subject to errors. Structured sequence deals with transforming data sequences into “better sequences,” having structured redundancy [4].

Before we discuss the detail of structured redundancy, let us describe the two basic ways such redundancy is used for controlling errors.

Error detection and retransmission: utilizes parity bits (redundant bits added to data) to detect that an error has been made and requires two-way link for dialogue between the transmitter and receiver, for example ARQ (Automatic Repeat Request): discard the frame received after error detection and request of retransmission the protocol used LADP or LAP-Dm.

Forward error correction (FEC): requires a one way link only, since in this case the parity bits are designed for both the detection and correction of errors [4]. Exploit the redundant of messages sent error correction, for example GSM use block Code Cyclic CRC: (Cyclic Redundancy Check) in simple detection Conventional code with Viterbi Algorithm assure efficacy error correction. Viterbi Algorithm (VA) is optima solution maximum likelihood estimation of states sequences of Markov processes with discrete time and finite numbers states observed in memo less noisy [5].

After channel coding the bits rate becomes 22, 8 Kbits/s for TCH/FS: 11.4 Kbits/s, TCH/HS: 13 Kbits, and the real bits rate is 24.7kbit/s, we add synchronization bits we get 33.875kbit/s. The bits to transmit are protected against errors it is the price to pay.

C. Interleaving / Deinterleaving

An interleaving rearranges a group of bits in a particular way. It is used in combination with FEC codes in order to improve the performance of the error correction mechanisms. The interleaving decreases the possibility of losing whole bursts during the transmission, by dispersing the errors. Being the errors less concentrated, it is then easier to correct them.

D. Encryption / Decryption

Confidentiality and security are weak for transport information through the radio channel .The mobile system communication has supplementary security functions for protection of subscribers and operators. The use of TMSI (Temporary Mobile Subscriber Identity) avoids the interception of IMSI (International Mobile Subscriber Identity). Also Authentication and ciphering are essential in GSM network [2].

- Random number RAND for authentication.
- SRES for authentication after calculation with Ki Key and Algorithm A3.
- Algorithm A5 for ciphering after calculation of Kc.
- Kc is calculated with Ki and Algorithm A8.

All parameters are shown in Fig. 6.

E. Modulation / Demodulation

Modulation is the process where the baseband data bit are converted into an analogue signal at the frequency. The analogue signal designed to match both the transmission requirements of the medium and any imposed by the system design and operation. GSM use a digital modulation techniques called Gaussian Minimum Shift Keying (GMSK) .The advantages of digit modulation are as follows: Greater noise immunity. Robustness to channel impairments, easier multiplexing of various forms of information and greater security, they accommodate digital error-control codes which detect and correct transmission errors and support complex signal conditioning and processing techniques to improve the performance of overall communication link [4]. The GMSK used as modulation with frequencies: 890 to 915 MHz mobile to base for uplink, 935 to 960 MHz base to mobile for downlink.

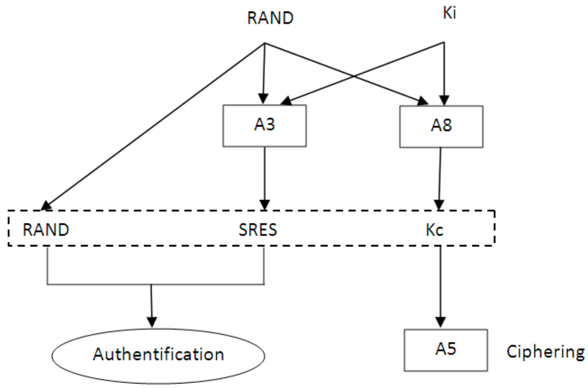

Fig. 6. Algorithmes used in authentification and ciphering

IV. Information Theory and Signal Porcessing between BTS/BSC and BSC /MSC

The concept in this section is the same as Section III.

We summarize and give some information and results: Base transceiver stations (BTS) are the actives equipments involve in transmission and reception of GSM signals. It contains many transmitters /receivers (TRX) connect to one or many antennas. The essential function of stations is to assure the transmission of radio signal from and to the mobiles and equipments: The cover each cell is assure by BTS with enough capacity (channel number for communications). The transmission between BTS and BSC is PDH (Plesiochronous digital hierarchy) with modulation QPSK (Frequency 15 GHZ). An example of Radio Performance of BTS:

- Support GSM900 (E-GSM), GSM1800 and GSM850
- Dual band configurations
- DR (Dual Rate), EFR (Enhanced Full Rate), AMR.
- Support several A5 ciphering algorithms (A5/0, A5/1 and A5/2).

Voice coded in the 64 kbps PCM (pulse code modulation) format in a PSTN network. The Abis interface between BTS and BSC, therefore, uses the 64 kbps PCM (or four multiplexed 16 kbps channels) format .The transmission bits rate is 2Mbits/s between BTS and BSC.

Each BTS is controlled by BSC (Base Station Controller): the GSM network comprise some BSC witch each one control many BTS.T he BSC is responsible of all functions related to radio transmission like handover, resource management of network (frequency occupation ..) it is able de handle many hundreds of cells simultaneously.[5]. The equipment TRAU is installed between MSC / BSC in MSC site as shown in Fig. 7.

The characteristics For Digital transmission SDH (Synchronous digital hierarchy) are:

- Radio frequency : 18, 23 & 26 GHz

- Modulation : 32QAM.
- MUX interface 155.52 MB/s (STM-1 optical or electrical).
- Output power TX: 18dBm
- FEC: MLCM (multi-level coded modulation) + Reed Solomon.

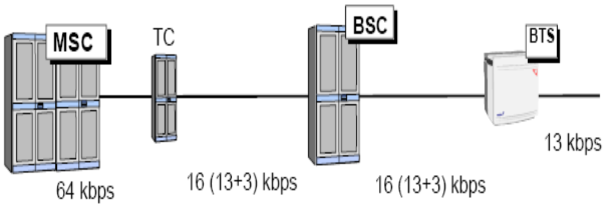

Fig. 7. Fonction of TRAU for voice code in MSC site.

V. GSM Protocol Stack

The layered model of the GSM architecture integrates and links the peer-to-peer communications between two different systems. The underlying layers satisfy the services of the upper-layer protocols. Notifications are passed from layer to layer to ensure that the information has been properly formatted, transmitted, and received.

The GMS protocol stacks diagram is shown in Fig. 8:

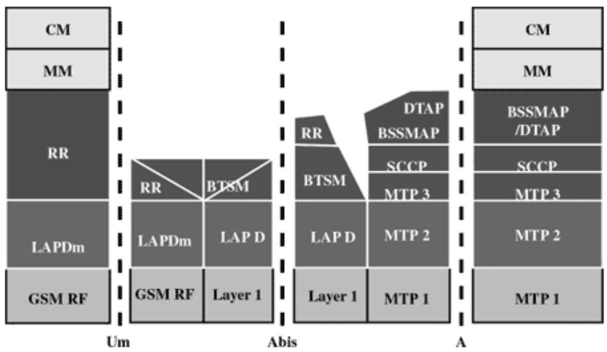

Fig. 8. GSM protocols layers for signaling

A. MS Protocols

The signaling protocol in GSM is structured into three general layers, depending on the interface.

Layer1: The physical layer, which uses the channel structures over the air interface.

Layer2: The data-link layer. Across the Um interface, the data-link layer is a modified version of the Link access protocol for the D channel (LAP-D) protocol used in ISDN, called Link access protocol on the Dm channel (LAP-Dm). Across the A interface, the Message Transfer Part (MTP), Layer 2 of SS7 is used.

Layer 3: The third layer of the GSM signaling protocol is divided into three sub layers: Radio Resource management (RR), Mobility Management (MM) and Connection Management (CM).

B. BSC Protocols

After the information is passed from the BTS to the BSC, a different set of interfaces is used. The Abis interface is used between the BTS and BSC. At this level, the radio resources at the lower portion of Layer 3 are changed from the RR to the Base Transceiver Station Management (BTSM). The BTS management layer is a relay function at the BTS to the BSC.

The RR protocols are responsible for the allocation and reallocation of traffic channels between the MS and the BTS. These services include controlling the initial access to the system, paging for MT calls, and the handover of calls between cell sites, power control, and call termination. The RR protocols provide the procedures for the use, allocation, reallocation, and release of the GSM channels. The BSC still has some radio resource management in place for the frequency coordination, frequency allocation, and the management of the overall network layer for the Layer 2 interfaces. From the BSC, the relay is using SS7 protocols so the MTP3 is used as the underlying architecture, and the BSS mobile application part or the direct application part is used to communicate from the BSC to the MSC.

C. MSC Protocols

At the MSC, the information is mapped across the A interface to the MTP Layers 1 through 3 from the BSC. Here the equivalent set of radio resources is called the BSS MAP. The BSS MAP/DTAP and the MM and CM are at the upper layers of Layer 3 protocols. This completes the relay process. Through the control-signaling network, the MSCs interact to locate and connect to users throughout the network. Location registers are included in the MSC databases to assist in the role of determining how and whether connections are to be made to roaming users. Each user of a GSM MS is assigned a HLR that is used to contain the user's location and subscribed services. A separate register, the VLR, is used to track the location of a user. As the users roam out of the area covered by the HLR, the MS notifies a new VLR of its whereabouts. The VLR in turn uses the control network (which happens to be based on SS7) to signal the HLR of the MS's new location. Through this information, MT calls can be routed to the user by the location information contained in the user's HLR [6].

VI. Conclusion

In this paper we have done a new method of presentation of telecommunication network using ENSI with cascade configuration, getting more information about techniques in information theory and signal processing in all steps of the process of data transmission. We have also seen the new concept of cascade configuration needed especially for complex network. Other concept must be mentioned are protocols and its relation with information theory and signal processing, for example the protocol LADP or LAP-Dm: (Layer 2 in GSM) used in channel coding. It is not enough we can do more for future works, we can describe deeply these methods in other networks like: GSM, GPRS, EDGE, UMTS, HSPA and LTE , including BSS equipments, NSS equipments, SDH equipments and IN equipments.

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