EVOLUTION OF
TELECOMMUNICATION
PROTOCOLS

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The monograph "Evolution of Telecommunication Protocols" is devoted to a wide range of questions related to signaling protocols in telephone networks of former USSR Public Switched Telephone Networks.

The SDL-oriented analysis method enabling the description in a relatively simple way of the specifics of interoffice signaling systems and call handling procedures, as well as specifications and scenarios required for designing is discussed. The evolution of Russian interoffice signaling systems, from three-wire trunks and so called "R 1.5" to Signaling System No.7 protocols is considered. All engineering solutions are directed toward up-to-date digital switching nodes and exchanges.

The book is primarily intended for engineers and scientists involved in the research, development, and operation of switching nodes. The book will be a valuable reference source for students and post-graduates studying in these areas.

Technical edition

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Preface

The rapid growth of telecommunications in recent years has necessitated the evolution of increasingly powerful and complex signaling protocols for public switched telephone network (PSTN). To operate effectively in this dynamic industry requires an understanding of the evolution principles and how signaling protocols connect different telecommunication systems, very new and existing ones.

The book is intended to fill up a gap in the telecommunications literature by gathering in one place at least some of more important PSTN signaling systems. It is an attempt of generalized and, to some extent, formalized description of PSTN signaling systems, including those used in the telephone networks of East Europe (Russia and C.I.S.). The East European PSTN and signaling protocols, for rare exceptions, have never been discussed and considered in publications. Hence, this book is a first balanced coverage of these aspects.

The account of the material begins (Chapter 1) with the consideration of signaling protocol evolution in telephone networks, the fundamentals for the classification of different signaling modes. Here, signaling itself is proposed to be defined as the life-blood of telecommunications networks that transforms an inert multitude of network nodes and transmission systems into a powerful medium for providing telecommunication services.

Chapter 2 introduces the methodology for the representation of signaling protocols based on the Specification and Description Language (SDL). First of all, an introduction to SDL sufficient for further understanding of the book is provided, and then some basic concepts of SDL-2000 helpful for more detailed specifications of signaling protocols are considered. The same approach is used in the next section devoted to the MSC language, in which the signal exchange scenarios presented further in the book are written.

The major attention is focused on specific Russian and other former USSR countries signaling systems. Chapter 3 covers the two-bit channel-associated signaling protocols, and Chapter 4 – the tree-wire analog trunk signaling employing the analogous logic. Chapter 5 is devoted to the description of the single and two voice-frequency signaling systems widely used in East European countries, and Chapter 6 discusses the
multifrequency signaling systems, the multifrequency shuttle in particular. Probably, it is due to this signaling protocol utilizing the same frequencies as the CCITT R1 protocol, and the logic close to the CCITT R2 protocol, that the aggregate of the signaling protocols described in sections 3.2, 3.3, and 6.1 has been given a rather witty "folklore" name "R one and a half" (R1.5).

Chapter 7 presents different one-bit channel-associated signaling protocols used in rural telephone networks ("norka" code, inductive code).

Functionality of East European telephone networks is associated with a number of specific call handling procedures, including toll operator intrusion into the called subscriber conversation, Automatic Number Identification (ANI) of the calling party, etc. These are considered in Chapter 8.

Chapter 9 outlines the international signaling systems, including CCITT R1 and R2.

Chapter 10 deals with the up-to-date Signaling System No.7. Side by side with a detailed description of this international protocol, the specific features in national versions of the protocol are outlined.

The last chapter, Chapter 11, discusses various tools for analyzing, testing, and converting the signaling protocols. Some mathematics is used for calculating the capacity of trunk groups, evaluating the time-probability characteristics of signal processing procedures, etc. All results are presented at engineering level, and references are provided for those who want to go deeper with the investigation of these problems.

The evolution of telecommunication signaling systems is described on the set of examples of Russian PSTN. This is very actually now, when all other world's networking industry has undergone a veritable meltdown in the financial market. Also, throughout it, readers will find information on the requirements adopted by telecommunication approvals authorities in East Europe.
Chapter 1
Signaling principles in telecommunications networks

1.1 Signaling in PSTN

The need for signaling via inter-exchange trunks, as well as a concept of telephone traffic concentration in circuit-switched exchanges itself, arise naturally from impossibility to arrange permanent each to each connections for millions of subscribers wishing to communicate with each other. Irresistible economical limitations forced another configuration of the telephone networks to appear, based on switching exchanges (offices), connected to each other by trunks. Though there is a finite call loss probability due to absence of idle trunks, this conceptual approach fits the major part of subscribers taking into account acceptable cost of communication services.

The term “Automatic Telephone Exchange” or “Central Office” (CO) appeared in the epoch of manual telephone switches (1880-1910) and is connected with the invention of A. B. Strowger, Kansas City. The epoch of electro-mechanical exchanges superseded manual exchanges (1910-1960) and contained stages of step-by-step exchanges, machine systems and crossbar exchanges, and in the 60’s the epoch of electronic exchanges came. Electronic switching systems had also 3 stages of development: space-division switching of analog signals with stored program control (1965-75), time-division switching of digital signals with centralized program control (1975-85), and digital exchanges with distributed microprocessor-based software and distributed digital switching (after 1985). It is assumed, that the latter technology will be in use until the second decade of the XXI century, with gradual inculcation of packet (IP)
and broadband (ATM) switching, new standards and protocols, but with
the conception of Signaling System No.7 (SS7) being maintained as
a foundation for world-wide telecommunication network development.

In Russia, the epoch of manual switches began in November, 1881,
when the Telegraph Department of Ministry for Internal Affairs signed
a concession for constructing and operating public telephone networks
in Petersburg, Moscow, Warsaw, Odessa, and Riga for a term of 20 years.
The owner of the concession, an engineer von Baranoff, however, resold
all rights to Bell Telephone Co. (USA), that built, equipped and launched
in 1882-83 the telephone networks in these 5 cities. The telephone com-
pany offices were equipped with one-wire switches of Gileland’s system.

The first Russian manual switches were manufactured in the plants of
Ufa province (Simka-plant, Asha-Balashovsky plant and Mingarsky plant).
Perhaps, this fact was taken into account nearly a hundred years later
when choosing a site for a new factory manufacturing the obsolete French
Stored Program Control exchanges MT-20.

By the beginning of 1917, the telephone network of Russia served
232000 subscribers, half of them being located in Petrograd and Mos-
cow. Within several subsequent years, 2/3 of this capacity had been de-
stroyed and by 1922 the number of subscribers was only 89000. At that
time, the People’s Commissar of Posts and Telegraphs V. N. Podbelsky
wrote: “We must put the Soviet Russia telephone at the top level of techni-
cal perfection. Undoubtedly. We must work out such form of telephone
management, when the most possible way of telephone management is
reached with the least expenses and the best result in terms of the build-
ing extension and regular telephony control – this is undoubtedly as well.
But it is not this work itself we aim at, it is but just a step on the way to
placing the telephone at the people’s disposal.”

It is likely, that a reader has already evaluated a fantastic actuality of
these words in Russia today, 80 years later. Goals were put absolutely right,
though means to reach them in that time have been selected incorrectly. If
so, a reader has a possibility to make everything better. Development of
telecommunications, as well as other branches of technology and science,
is guided by an ancient orient saying “It is a walker who will overcome the
way”, and if this book appears somehow useful on that way, the author
would consider his goal achieved.

Anyhow, throughout its history the telephone network of Russia and
the USSR has been developing and growing as one of the biggest net-
works in the world.

The first automatic exchange of 6000 numbers capacity was put into
operation in Rostov-on-Don in 1929. In the end of the World War II, the
ATS-47 Russian step-by-step automatic exchange was designed. In 1954,
the “Krasnaya Zarya” plant and LONIIS created a new generation of step-
by-step exchanges ATS-54. In 1957 in Leningrad, the first automatic cross-
bar exchange of 100 numbers capacity was set up. Later in LONIIS, under direction of professor Boris Livshiz, together with the “Krasnaya Zarya” plant the large capacity crossbar exchange was designed, and in 1967-68 the Russian crossbar exchange ATSK of 30000 numbers capacity was installed on Kalininsky prospect, Moscow. The crossbar exchanges of LONIIS design were being manufactured also in Germany (GDR) and Czechoslovakia.

Nowadays, these step-by-step exchanges (ATS-47, ATS-54) and crossbar exchanges (ATSK, ATSK-U, ATSK-100/2000, PSK-1000), that make up about 23% and 52% of urban public switched telephone network (PSTN) capacity, accordingly, are still in operation in Russia. The remaining 25% are quasi-electronic and electronic digital exchanges.

Total installed capacity of rural telephone networks is 3.8 million numbers, served almost on the whole by crossbar exchanges (ATSK 100/2000 and ATSK 50/200).

A generic Urban PSTN (UTN) structure is represented in Figure 1.1. Here, a telephone network of a big metropolitan area, such as Moscow or St. Petersburg, is shown. Such network features a 7-digit closed numbering plan and ensures the connection of up to 8 million of subscriber lines. Within a PSTN, each local exchange (central office) is connected (usually, through incoming and/or outgoing tandem switch) to the toll exchange, special services node (SSN) and several other local exchanges.

Legend: CO – Central Office (Local Exchange)  
OT – Outgoing Tandem Switch  
IT – Incoming Tandem Switch  
SSN – Special Services Node  
OP – Operator Positions  
SL – Trunks  
SLM – Toll Switched Trunks  
ZSL – Toll Connecting Trunks
Telephone networks are extremely complex, both in terms of the technology needed to provide services and the operational support that is necessary to maintain effective working. For all these functions to be realized, the signaling between exchanges is needed. This signaling provides for the call control information transfer within a network, as well as between subscribers and a telecommunication network.

So, what is signaling? According to an expression by R. Manterfield, signaling is the blood circulatory system of telecommunication networks. It provides the bond that holds together the multitude of transmission links and switching nodes in a network to provide a cohesive entity. Without signaling, networks are lifeless. By providing effective signaling systems, a network is transformed into a tremendously powerful medium through which people can communicate with each other using a progressively extended range of telecommunication services. The critical nature of signaling is driving its rapid evolution. Old, still existing signaling systems that were simple mechanisms for transferring basic information are being gradually replaced by more powerful data transfer protocols that provide effective and seamless transfer of information between switching nodes and exchanges.

1.2 Classification of telephone signaling systems

The inter-exchange signaling information is transferred by various methods, which can be divided into 3 major classes.

Class 1 – the transfer of signaling information directly down a voice channel (speech path), called “in-band” signaling. Signals can be transferred on voice channels (physical circuits) by direct current (DC signaling), voice-frequency currents (voice-frequency signaling), inductive pulses, and others.

Class 2 – channel-associated signaling (CAS). As a rule, such systems provide dedicated signaling information transmission facilities for each speech channel of an information transmission link. It may be TS16 in a PCM link, a dedicated frequency channel outside a speech band of a VF channel at 3825 Hz, and others.

Class 3 – common channel signaling systems (CCS). In the protocols of this class, a signaling data link is allocated to a bunch of telephone channels according to an address-group principle, i.e. the signals are transmitted in accordance with their addresses and are placed in a common buffer for utilizing by each telephone circuit how and when it is needed.

Signaling systems of the first two classes were designed to be used in telephone networks utilizing old technologies, where switching nodes and CO are, for the most, electromechanical ones (crossbar and step-by-step). Not only Russian telephone networks, but also most of the
national telecommunication networks all over the world still contain the equipment where these signaling systems are used. Even with introduction of the most advanced CO, interaction with existing signaling systems is needed. That is why description of principles and signaling systems of the first two classes is the big part of this book. Descriptions of signaling systems most widely distributed in telephone networks of Russia and other former USSR republics are brought to the level of formalized specifications and can serve as basis for their implementation in modern digital switching nodes and CO.

The common channel signaling system No.7 (SS7) is optimal for using in networks where modern digital switching and program control technologies are applied, and that’s why a special chapter of the book is devoted to ISUP-R and other SS7 protocols. This book is not intended as an exhaustive account of the SS7 signaling system: this is left for the specifications. So, whereas the specifications need to define network functioning modes under failure and error conditions, these are largely omitted from this description in chapter 10 to enable the reader to concentrate on the SS7 protocol principles. Once the principles have been absorbed, the specifications will be much easier to read.

Such unequal approach to description of the signaling systems of different classes is accounted by the reasons as follows. Detailed specifications of common channel signaling system, that include SDL-diagrams, data structures, signal timer parameters, scenarios, etc., are being developed and perfected by the specialists of Study Group 11 of the ITU-T – International Telecommunications Union – Telecommunications Sector (former International Telegraph and Telephone Consultative Committee – CCITT according to the abbreviation came from the French translation of the name), and are published periodically in the ITU-T Colored Books, in particular Recommendations Q.700 published in the CCITT Yellow, Red and Blue Books (1981, 1985, 1989), and ITU-T White Book (1993). These specifications are available for a curious reader, along with other books on common channel signaling No.7. On the other hand, the SDL-diagrams, timer tables, signals interchange scenarios etc. for specific Russian signaling systems over voice channels and 2-bit CAS, and also for unique procedures of automatic number identification (ANI) had been created by the author, they are not to be found in publications, and it was only an ever increasing interest of Russian and foreign communications engineers in this problem over the recent years that made the author conceive the idea of writing this book.

Another, also pragmatic, reason for such difference in description detailing levels is relative simplicity of signaling systems logic, that allows their specifications to go into the limited volume of this book and to be easily appreciated by all readers.
1.3 Evolution of signaling protocols

One of the major factors influencing the existence of the above 3 classes of signaling systems is the relationship between signaling systems supported by this or that switch, and the call control principles used at the switch. Class 1 signaling systems are associated with analog step-by-step exchanges implementing direct control principle.

These exchanges constitute a number of independent selection stages, each having its own control mechanism and thus combining control and switching functions. Figure 1.2 gives a simplified presentation of inter-exchange class 1 signaling. During call handling process, the supervision/control and speech signals follow the same path within the exchange, and they also follow the same path external to the exchange, i.e. on the transmission link (inter-exchange trunk).

DC signaling may be implemented by galvanic, loop-disconnect and battery methods.

Battery mode: signals are transferred on a, b or c wires using exchange batteries and ground as reverse wire. This mode is detailed in chapter 4.

Loop-disconnect mode: signals are transferred without using ground as reverse wire, that is from exchange battery of a single exchange. In this case, possible ground voltage difference has no impact on signal transfer. The status of a DC loop on the speech circuit identifies the information being transferred. The use of loop-disconnect signaling on inter-exchange trunks is limited by: possible distance of DC signal transfer, necessity to bypass the amplifiers that do not let direct current pulses to pass through, and also by impossibility to operate over carrier channels with frequency division multiplexing (FDM). Nevertheless, these methods found use in urban and rural telephone networks.

Galvanic method (Figure 1.3) is characterized by: signaling circuits have galvanic connection even with transformers on a line. This signaling method...
Signaling principles in telecommunications networks

od is used in rural networks in case of rural exchanges being connected to manual telephone switches of central battery (CB) system and also for manual switches of local battery (LB) system in case of connection with exchange when MB switches are not equipped with 24 V power supply sources. A disadvantage of this method is that call control signals pass on both wires in one direction and, therefore, exert considerable inductive influence on adjacent circuits.

The inductive signaling method is used in rural telephone networks on trunks between a central rural exchange and nodal or end exchanges, and also between a nodal exchange and an end exchange interconnected via physical two-wire trunks. Polarized relays are used as inductive pulse receivers. A positive feature of this method is a possibility to create artificial (phantom) circuits, that could have significance for rural telephone networks in certain cases.

The present state of local telephone network of Russia allows the author not to consider in details such signaling methods, as loop-disconnect, galvanic and inductive. Still, the latter method will be mentioned in chapter 7 to explain one-bit channel-associated signaling (1CAS) by inductive code. As regards the battery method of signaling on three-wire trunks, the whole chapter 4 is devoted to it, due to the fact that this signaling is still widely used in local telephone networks of Russia.

The next stage of switching exchange development is shown in Figure 1.4. Here, independent selection stages in step-by-step switches are replaced with switching units, and special control devices (registers and markers) separated from switching devices are introduced for setting up and releasing connections. Such technology leads to more flexibility in call control and is more economic. Class 2 signaling system – channel-associated signaling (CAS) – is usually associated with this class of exchanges. Signaling information follows the same path as corresponding speech, but they are separated within the exchange. This is shown in Figure 1.4, where speech telephone circuits (solid lines) are arranged by a switching unit, and signaling (dotted lines) is transferred and received by control devices of an exchange.
Appearance of this generation of switching exchanges also caused more active utilization of various alternating current (AC) signaling methods. All of them are based on different frequency signals: within the same frequency range as speech signals (300–3400 Hz) or lower (<300 Hz) and higher (>3400 Hz) frequency range. Figure 1.5 shows this distribution of frequency ranges.

Voice-frequency signaling means transfer of signaling information over the speech path this information relates to. Signaling information transfer is achieved by generating one or more signaling tones and sending them through the related speech path. On the other end, information is analyzed by means of tone receivers.

In inter-exchange transmission links, these signals are processed in the same way as speech: to process a signal the speech path amplifiers are used, allowing the signaling utilization distance to be considerably increased against DC systems.

Voice-frequency signaling systems may be used for line (supervision) and register signaling; for register signaling, utilizing a special type of voice-frequency signaling, so called multifrequency signaling systems.
Signaling principles in telecommunications networks

considered in this chapter below and described in detail in their specific Russian versions in chapter 6, is more effective.

Supervision voice-frequency signaling may be realized by sending a frequency (or combination of two frequencies). The signal meaning is determined by the direction of the signal, the frequency of the signal and the point in the call handling process at which the signal is sent. In supervision signaling, continuous non-compelled signaling protocols are used. In continuous non-compelled signaling systems, the information being transferred is denoted in the change of state of the tone (tone-on/tone-off). The term "non-compelled" means that an acknowledgment of a signal is not required to stop the sending of the signal. An example of this type of signaling is Bell SF system (Table 1.1).

Table 1.1 Example of a continuous non-compelled signaling system (Bell SF)

<table>
<thead>
<tr>
<th>Signal</th>
<th>Forward Signal</th>
<th>Backward Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle state</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>Seizure</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>Answer</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Clear forward</td>
<td>ON</td>
<td>N/A</td>
</tr>
</tbody>
</table>

In pulsed voice-frequency signaling systems, the information is transferred by timed pulses of tone. Hence, the meaning of the signal is determined by the direction of the signal, the length of the pulse and the point during the call handling when the signal is sent. The advantages of the pulsed form of voice-frequency signaling are that a larger repertoire of signals is available (thus allowing more features), higher signaling levels are possible (due to the non-continuous nature of the signals) and there is less interference with the signals (again due to their non-continuous nature). However, the need to meet the tolerances required for effective signal recognition means that the signaling terminals are relatively complex and hence expensive. Examples of pulsed voice-frequency signaling systems are: Russian single voice-frequency signaling system 2600Hz, described in chapter 5, or English signaling system AC9, shown in Table 1.2.

Table 1.2 Example of signals in a pulsed voice-frequency signaling system (UK AC9 system)

<table>
<thead>
<tr>
<th>Signal</th>
<th>Tone Pulse (frequency 2280 Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seizure</td>
<td>70 ms</td>
</tr>
<tr>
<td>Digits</td>
<td>60 ms</td>
</tr>
<tr>
<td>Answer</td>
<td>250 ms</td>
</tr>
<tr>
<td>Clear forward</td>
<td>Greater than 700 ms</td>
</tr>
</tbody>
</table>

Voice-frequency signaling systems can be used in two modes: link-by-link and end-to-end. In link-by-link signaling all address information is processed in each exchange. According to Figure 1.6, signals arrive from
Exchange A to Exchange B at first and then Exchange A transmitter gets free. Then Exchange B sends all information to Exchange C, and in this case each exchange processes address information before sending it to a next exchange.

In end-to-end signaling signals between outgoing and incoming exchanges are transferred directly over the speech path, without transformation or/and analysis at intermediate switching nodes. Hence, signals (e.g. the answer signal) can be transferred very quickly. As shown in Figure 1.7, calling subscriber exchange register (Reg.) is used for all time of connection set up, and calling subscriber exchange marker (M) sends to a next exchange only information that is needed for call routing. After that Exchange A sends information to Exchange C, and register of Exchange B is free at once after routing from Exchange B to C is completed.

Out-band signaling systems are typically used in frequency-division-multiplexing (FDM) transmission systems. In these systems each speech channel is placed in frequency spectrum of 4 kHz, for speech only 300÷3400 Hz range is used, and for signaling – remaining part of 3400÷4000 Hz range (3825 Hz is recommended).

Advantages of out-band signaling systems include the ability to signal during speech and the avoidance of measures to overcome the imitation of signals by normal speech. A disadvantage is that these signaling systems can only be applied on transmission systems that permit a wider frequency spectrum than normal non-multiplexed transmission systems. Hence, it is usually limited to appropriate FDM transmission systems.
The nature of out-band signaling allows it to be used in numerous modes, including the continuous mode and pulsed mode, described above for voice-frequency signaling. A common implementation is the continuous non-compelled mode, using either “tone-on when idle” or “tone-off when idle” system.

An example of a tone-on idle system is the supervision signaling for CCITT R2 described in chapter 9. An example of a typical tone-off idle implementation (English signaling system AC8) is given in Table 1.3.

Table 1.3 Example of signals in typical "tone-off when idle" system (UK AC8 System)

<table>
<thead>
<tr>
<th>Signal</th>
<th>Forward Tone</th>
<th>Backward Tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Seizure</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>Digits</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>Answer</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Clear forward</td>
<td>Off</td>
<td>–</td>
</tr>
</tbody>
</table>

Signaling systems of the first two classes, shown in Fig. 1.2 and 1.4, have limited signaling capabilities, in particular, by limited number of signals (for example, because of limited number of loop states or frequency combinations) and by limited transmission capabilities (e.g. it is impossible to send signals by speech range frequencies during conversation without taking special measures).
Another limitation is “speech clipping”. In some signaling protocols, it is necessary to have the speech path being disconnected during call set-up to avoid tones being heard by the calling subscriber. This results in a slow return of the answer signal and, if the called subscriber starts speaking immediately after answer, then the first part of his phrase may be lost.

All these things appeared to be reasons for creating the third, mentioned at the beginning of this paragraph, class of common channel signaling. The principle of common channel signaling is to separate totally the signaling path from the speech path (Fig. 1.8).

![Fig. 1.8 General structure of Common Channel Signaling](image)

In addition to eliminating the above restrictions, there were other reasons that caused common channel signaling systems to be adopted throughout the world in national and international telecommunication networks, namely: the rapidly developing program control techniques of exchanges; the inherent evolutionary potential of SS7 systems to create new features in accordance with Next Generation Network (NGN) requirements. SS7 is not just designed to meet current needs. It is designed to be as flexible as possible in meeting future requirements of NGN.

For skeptics, the author advises to compare chapter 10 with signaling protocols described in chapters 3 to 9.

1.4 Peculiarities of Russian signaling systems

In the very beginning of its activity, CCITT dealt with international signaling system specifications, permitting national signaling systems to be developed independently. Mostly it reflected on history of constructing the telephone network on the territory recently covered 1/6 of the globe. This is partly connected with lack of observance in the USSR to follow international standards, at least in telecommunications area. Even today, in the telephone network of the Russian Federation there are specific inter-exchange signaling protocols and call handling procedures that complicate implementation of the new telecommunications technologies.
The existing specific signaling protocols for Russian Telephone Networks have been designed to meet the crossbar and step-by-step exchange requirements and are reduced to the above-mentioned end-to-end signaling mode that provides connections between subscribers through physical circuits. For digital exchanges, the “link-by-link” mode is more preferable. It sometimes results in paradoxical situations, when the old electromechanical switches can provide better performance than new digital exchanges. The reason is that protocols very often do not permit using all advantages of modern technology though they were good enough for electro-mechanical switches. Nevertheless, necessary support of these protocols would be the main requirement for new digital exchanges. Chapters 3 – 7 try to explain: what are the Russian telephone network signaling protocols, how they work, how they could be checked, what is their inner logic, etc. Here, only most important factors are described.

One of such factors is availability of two types of inter-exchange trunks: outgoing and incoming local trunks (1) and incoming toll trunks (2). The reason of it is the difference in local and toll incoming calls processing and it results in organization of different physical groups of trunks on PSTN. In this connection it is helpful to recall Figure 1.1 showing local telephone network of a big city with 7-digit numbering and capacity about 8 millions of subscriber lines (the first digits “8” and “0” are reserved as access code to a toll exchange and access code to a special services node). In rural networks, the line group capacity is relatively small, they are more expensive, their utilization is much lower, and that’s why common trunk groups are used more often, and different call processing functions are provided by appropriate signaling protocols.

Another factor is that only toll (long-distance) calls are charged in practically all local networks (calls passing through a toll exchange), along with priority processing of toll calls. To implement the charging system existing at present in the PSTN of Russia, the calling subscriber category and number information must be transmitted to a toll exchange which, in turn, provides possibility of automatic number identification (ANI) remotely for each local network subscriber. The technical solution adopted to solve this problem is oriented to networks with electro-mechanical exchanges (and is described in chapter 8). Moreover, processing of incoming toll call by a destination exchange differs from processing of a local call and needs a special signaling protocol. In particular, a destination local exchange should define status of the called subscriber line and send this information to a toll exchange.

Classification of supervision (line) signaling systems used in rural and urban telephone networks is given in Tables 1.4 – 1.5 containing list of physical interfaces between exchanges in 1.4 and list of signaling logics in 1.5. Such division in physical and logic levels of a signaling protocol is used in all chapters.
As a main physical interface for urban telephone networks a digital 2.048 Mb/s interface called E1 is used in accordance with ITU-T Recommendations G.703, G.711, and the basic signaling system represents 2 dedicated signaling channels in TS16 and with independent groups of outgoing/incoming local and incoming toll trunks. 2.048 Mb/s interface is also preferable in rural networks, but this interface is used for universal both-way trunks and that’s why another signaling logic is used. On rural telephone networks the other types of PCM equipment such as PCM15 (1.024 Mb/s) and even PCM12 may be also used. Use of PCM12 is being reduced, but PCM15 is still widely used, though it doesn’t match with any international standard.

We can’t but mention that all these systems are specific and non-compatible with international standards. It does not concern SS7 that is used now in Russian telephone networks. The national technical peculiarities have small impact on SS7 described in chapter 10. It enables the new digital exchanges to be installed in the PSTN of Russia without difficulties, described in chapters 3-8.

Table 1.4 Some signaling system interfaces (physical level)

<table>
<thead>
<tr>
<th>Type</th>
<th>Application Area</th>
<th>Described</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.048 Mb/s PCM</td>
<td>Everywhere</td>
<td>Chapter 3</td>
<td>ITU-T G.711, G.703</td>
</tr>
<tr>
<td>1.024 Mb/s PCM</td>
<td>Rural Networks</td>
<td>Chapter 7</td>
<td>Specific</td>
</tr>
<tr>
<td>3/4 wire trunks</td>
<td>Everywhere</td>
<td>Chapter 4</td>
<td>Specific</td>
</tr>
<tr>
<td>2 wire inductive</td>
<td>Rural Networks</td>
<td>Chapter 7</td>
<td>Specific</td>
</tr>
<tr>
<td>4/6 wire TL</td>
<td>Everywhere</td>
<td>Chapter 3, 5</td>
<td>Specific E&amp;M</td>
</tr>
</tbody>
</table>

As a main physical interface for urban telephone networks a digital 2.048 Mb/s interface called E1 is used in accordance with ITU-T Recommendations G.703, G.711, and the basic signaling system represents 2 dedicated signaling channels in TS16 and with independent groups of outgoing/incoming local and incoming toll trunks. 2.048 Mb/s interface is also preferable in rural networks, but this interface is used for universal both-way trunks and that’s why another signaling logic is used. On rural telephone networks the other types of PCM equipment such as PCM15 (1.024 Mb/s) and even PCM12 may be also used. Use of PCM12 is being reduced, but PCM15 is still widely used, though it doesn’t match with any international standard.

We can’t but mention that all these systems are specific and non-compatible with international standards. It does not concern SS7 that is used now in Russian telephone networks. The national technical peculiarities have small impact on SS7 described in chapter 10. It enables the new digital exchanges to be installed in the PSTN of Russia without difficulties, described in chapters 3-8.

Table 1.5 Some local network signaling protocols

<table>
<thead>
<tr>
<th>Type</th>
<th>Application Area</th>
<th>Described</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUPERVISION SIGNALING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2CAS for independent groups</td>
<td>Urban Networks</td>
<td>Chapter 3</td>
<td>Different protocols for incoming and outgoing trunks</td>
</tr>
<tr>
<td>2CAS for universal both-way trunks</td>
<td>Rural Networks</td>
<td>Chapter 3</td>
<td>One protocol for all trunks</td>
</tr>
<tr>
<td>1CAS “Norka”</td>
<td>Rural Networks</td>
<td>Chapter 7</td>
<td>Different protocols for incoming and outgoing trunks</td>
</tr>
<tr>
<td>1CAS “Norka”</td>
<td>Rural Networks</td>
<td>Chapter 7</td>
<td>One protocol for all trunks</td>
</tr>
<tr>
<td>Single-frequency signaling</td>
<td>Long distance and Private Networks</td>
<td>Chapter 5</td>
<td>Different protocols for incoming and outgoing trunks</td>
</tr>
<tr>
<td>Two-frequency</td>
<td>Trunk Networks</td>
<td>Chapter 5</td>
<td>1200 Hz + 1600 Hz</td>
</tr>
<tr>
<td>3/4 wire analog trunks</td>
<td>Everywhere</td>
<td>Chapter 4</td>
<td>Urban and Rural Networks</td>
</tr>
<tr>
<td>REGISTER SIGNALING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multifrequency shuttle</td>
<td>Everywhere</td>
<td>Chapter 6</td>
<td>For Urban PSTN</td>
</tr>
<tr>
<td>Multifrequency gapless packet</td>
<td>Calling Party Number Identification</td>
<td>Chapter 6</td>
<td>Only for ANI</td>
</tr>
<tr>
<td>Multifrequency packet</td>
<td>Between Urban CO and Toll Exchange</td>
<td>Chapter 6</td>
<td></td>
</tr>
<tr>
<td>Decadic Code</td>
<td>Everywhere</td>
<td>Chapter 3, 4, 5, 7</td>
<td>For Urban and Rural PSTN</td>
</tr>
</tbody>
</table>
1.5 Adaptation and certification aspects

Specific features of existing signaling systems and call handling procedures have necessitated an additional technical development for implementing them. This book serves to support such technical development and adaptation approval tests.

The interface specification methods and tools standards, rules and procedures for connecting a new exchange to Russian and CIS countries PSTN, and also set of protocol-testers, methodologies, simulation and measurement devices to test and verify these specifications, should be added to the information contained in this book.

The general scheme of specific signaling systems and call handling procedures development (adaptation), debugging, tests and official approval is shown in Figure 1.9. Technical Terms and Conditions (TT&C) doc-
ocument is issued for every particular telephone system. Table 1.6 gives contents of TT&C document for a local exchange as an example. This document contains, together with the description of the telecommunications equipment and the field of its application, the most general national specifications written in “a natural language” with all typical shortcomings that such text specifications have: the ambiguity, impossibility to support semantics of description at the same detailing level, etc.

Table 1.6  Contents of the “Technical Terms and Conditions (TT&C)” document

<table>
<thead>
<tr>
<th>1</th>
<th>Introduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Subject of TT&amp;C</td>
</tr>
<tr>
<td>1.2</td>
<td>Field of Application</td>
</tr>
<tr>
<td>1.3</td>
<td>General Description of the System</td>
</tr>
<tr>
<td>2</td>
<td>Specifications</td>
</tr>
<tr>
<td>2.1</td>
<td>Exchange Capacity, Traffic</td>
</tr>
<tr>
<td>2.2</td>
<td>Connection Types, Basic Types of Communications</td>
</tr>
<tr>
<td>2.3</td>
<td>Types of Subscriber Lines and Sets, Categories of Subscribers, and Service Types</td>
</tr>
<tr>
<td>2.4</td>
<td>Subscriber Line Parameters</td>
</tr>
<tr>
<td>2.5</td>
<td>Subscriber Signaling</td>
</tr>
<tr>
<td>2.6</td>
<td>Types and Parameters of Trunks</td>
</tr>
<tr>
<td>2.7</td>
<td>Signaling on Trunks</td>
</tr>
<tr>
<td>2.8</td>
<td>Release Principles</td>
</tr>
<tr>
<td>2.9</td>
<td>Transmission Characteristics</td>
</tr>
<tr>
<td>2.10</td>
<td>Communication with Local Telephone Network</td>
</tr>
<tr>
<td>2.11</td>
<td>Tones and Ringing</td>
</tr>
<tr>
<td>2.12</td>
<td>Automatic Number Identification (ANI) of a Calling Subscriber</td>
</tr>
<tr>
<td>2.13</td>
<td>Charging</td>
</tr>
<tr>
<td>2.14</td>
<td>Synchronization</td>
</tr>
<tr>
<td>2.15</td>
<td>Operation &amp; Maintenance</td>
</tr>
<tr>
<td>2.16</td>
<td>Quality of Service and Reliability</td>
</tr>
<tr>
<td>2.17</td>
<td>Resistibility to Climatic and Mechanical Effects</td>
</tr>
<tr>
<td>2.18</td>
<td>Resistibility to External Electrical and Magnetic Fields (EMC)</td>
</tr>
<tr>
<td>2.19</td>
<td>Spare Parts, Devices, Measurement Instruments, Consumable Materials</td>
</tr>
<tr>
<td>2.20</td>
<td>ISDN Services. Data and Non-Telephone Information Transfer</td>
</tr>
<tr>
<td>2.21</td>
<td>Equipment Installation</td>
</tr>
<tr>
<td>2.22</td>
<td>Control Devices</td>
</tr>
<tr>
<td>2.23</td>
<td>Software</td>
</tr>
<tr>
<td>2.24</td>
<td>Power Supply</td>
</tr>
<tr>
<td>2.25</td>
<td>Documentation Contents</td>
</tr>
<tr>
<td>2.26</td>
<td>Equipment Design</td>
</tr>
<tr>
<td>3</td>
<td>Security Regulations</td>
</tr>
<tr>
<td>4</td>
<td>Acceptance and Test Rules</td>
</tr>
<tr>
<td>5</td>
<td>Supervision Methods. List of Methods and Instructions, Used During Equipment Test, Acceptance and Operation</td>
</tr>
<tr>
<td>6</td>
<td>Operation &amp; Maintenance Instructions</td>
</tr>
<tr>
<td>7</td>
<td>Packing and Marking</td>
</tr>
<tr>
<td>8</td>
<td>Producer Guarantees</td>
</tr>
<tr>
<td>9</td>
<td>Changes Registration List</td>
</tr>
<tr>
<td>App.1</td>
<td>SOSM requirements</td>
</tr>
</tbody>
</table>
It should be noted that these TT&C’s shortcomings are characteristics of any text technical materials. To develop the signaling system interfaces, to implement the ANI procedure, and to provide interaction with an existing PSTN infrastructure, more detailed and formalized specifications are required. These specifications must be developed using such formal means as algorithmic languages, electric circuit construction rules, protocols, scenarios. Specifications include not only signaling codes tables, but also structure layouts and SDL-diagrams, timer tables, signal inter-change scenarios in MSC language. These specifications summarize measurement results accumulated for many years at Russian and other CIS countries PSTN where the historically formed technical situation requires the processing algorithm and timer value to be specifically selected when defining this or that supervision signal.

Efficiency of such specifications for implementing the specific signaling protocols is illustrated in Figure 1.10. Although the initial data for Figure 1.10 are expert estimations obtained as a result of private, fairly specialized research, high efficiency of detailed specifications is evident.

![Fig. 1.10 Distribution of labor consumption (cost) for signaling protocol development without (1) and with (2) detailed specifications](image_url)

The concept of hierarchical specifications for signaling systems to a certain degree correlates with the Boehm’s modern spiral model of software development and is shown in Figure 1.11. Some incompleteness of this model is reasoned by Persistent Changes Law of Biledi and Leman. “The system in use is under persistent changes until it becomes more profitable to freeze it and make it anew”.

Specification levels along the spiral (Figure 1.11) differ not only in the degree of concretization (increasing from the top downwards) but also by language means of description. Thus, presentation of specifications at
a higher level is like a “common ancestor” of the lower level presentation families, except for the first level (level of TT&C, using natural language). At the more detailed levels of development, the graphical syntax is applicable with Pascal-type notations which was united by experts of the ITU-T Study Group 10 into a single Specification and Description Language (SDL).

The methodology for SDL-based specifications is described in the next chapter.

The methodology, described in this chapter, contains no radically new, revolutionary principles. All methodology is based on the traditional development scheme, such as 'requirement-specifications-design-test', but is oriented on more resolute and consistent formalization of interfaces with the existing telephone network. Implementation of the whole complex of these methods for different signaling protocols is described in the next chapters. Some summarization in part of testing the signaling system implementations to comply with formalized interface specifications is described in chapter 11, the last one in this book.

Such a shift emphasis in a rather traditional combination of methods and procedures creates, in a sense, a new quality and allows us to hope that the author's attempt may appear helpful – if not as a guiding principle, then at least as one of the possible points of view.

Fig. 1.11 Spiral model of signaling system implementation process