Third-generation TDMA

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By adopting a common radio-access standard and a common core data-network standard, TDMA and GSM systems can share a common solution for third-generation networks.

The standardization of the first phase of EDGE is presently about to be finalized in the ETSI Special Mobile Group. Phase I of EDGE includes support for best-effort packet-data services with high data rates. Phase II, targeted for the end of 2000, will comprise support for real-time applications. Compared to present-day data services in GSM and TDMA systems, EDGE will provide significantly higher user bit rates and spectral efficiency. It can be introduced smoothly into these systems in existing frequency bands, reusing the cell planning of previously deployed networks.

In this article, the authors describe the concepts for introducing EDGE into TDMA systems, and address performance issues by means of system simulations.

Introduction

The standardization of third-generation mobile communication systems is rapidly progressing in all regions of the world. The work is based on the International Telecommunication Union's (ITU) recommendations for International Mobile Telecommunications-2000 (IMT-2000). By offering high data rates and multimedia capabilities, IMT-2000 systems will enhance the services provided by second-generation systems.[1]

GSM and TDMA (TIA/EIA-136) are two highly successful second-generation cellular standards:

- more than 256 million people in more than 120 countries subscribe to GSM; and
- the family of TDMA systems (including EIA-553 and IS-54) serves more than 115 million subscribers in over 100 countries.

The enhanced data rates for global evolution (EDGE) concept, which is a new time-division multiplexing-based radio-access technology, gives GSM and TDMA an evolutionary path for delivering third-generation services in the 400, 800, 900, 1800 and 1900 MHz frequency bands. The advantages of EDGE include rapid availability, the reuse of existing GSM and TDMA infrastructure, and support for gradual introduction. The excellent performance of EDGE has been demonstrated in a number of papers.[2-6]

Background

EDGE was first proposed to the European Telecommunications Standards Institute (ETSI) in 1997 as an evolution of GSM. A subsequent feasibility study (completed and approved by ETSI) paved the way for standardization.[7] Although EDGE reuses the GSM carrier bandwidth and timeslot struc-

BOX A, ABBREVIATIONS

136HS	136 High Speed
8PSK	Eight-symbol phase-shift keying
AC	Authentication center
ANSI	American National Standards Institute
ARQ	Automatic repeat request
BCCH	Broadcast control channel
BLER	Block error rate
BS	Base station
BSS	Base station system
BSSAP+	Enhanced BSS application part
BSSGP	BSS GPRS protocol
CDF	Cumulative distribution function
CFCCH	COMPACT frequency correction channel
C/I	Carrier-to-interference ratio
CPAGCH	COMPACT packet access grant channel
CPBCCH	COMPACT packet broadcast control channel
CPCCCH	COMPACT packet common control channel
CPPCH	COMPACT packet paging channel
CPRACH	COMPACT packet random access channel
CSCH	COMPACT synchronization channel
DCCH	Digital control channel
ECSD	Enhanced circuit-switched data
EDGE	Enhanced data rates for global evolution
EGPRS	Enhanced GPRS
EIA	Electronic Industries Association
ETSI	European Telecommunications Standards Institute
FCCH	Frequency correction channel
GGSN	Gateway GPRS support node
GMSC	Gateway MSC
GMSK	Gaussian minimum-shift keying
GPRS	General packet radio service
GPS	Global positioning system
GSM	Global system for mobile communication
HLR	Home location register
IMT-2000	International mobile telecommunications-2000
IR	Incremental redundancy
IS	Interim standard
ITU	International Telecommunication Union
IWMSC	Interworking MSC
LA	Link adaptation
LLC	Logical link control
LQC	Link quality control
MAC	Media access control
MC	Message center
MCS	Modulation and coding scheme
MSC	Mobile services switching center
MT	Mobile terminal
MTP	Message transfer part
OTAF	Over-the-air activation function
PACCH	Packet-associated control channel
PBCCH	Packet broadcast control channel
PCCCH	Packet common control channel
PDN	Packet-data network
PDTCH	Packet-data traffic channel
PTCCH	Packet timing advance control channel
QoS	Quality of service
RLC	Radio link control
RTT	Radio transmission technology
SC	Service center
SCCP	Signaling connection control part
SGSN	Serving GPRS support node
SME	Signaling message encryption
SMS	Short message service
TDMA	Time-division multiple access
TE	Terminal equipment
TIA	Telecommunications Industries Association
TN	Timeslot number
TOM	Tunneling of messages
TS	Timeslot
TU3	Typical urban 3 km/h
UWCC	Universal Wireless Communication Consortium
VLR	Visitor location register

ture, it is by no means restricted to use within GSM cellular systems. Instead it can be seen as a generic air interface for efficiently providing high bit rates. It thus facilitates an evolution of existing cellular systems toward third-generation capabilities.

While developing third-generation wireless technology, the TDMA community chose to adopt an evolutionary approach, basing its proposal for third-generation technology on the evolution of current second-generation systems. The Universal Wireless Communication Consortium (UWCC) proposed the 136 High-Speed (136HS) radio interface as a means of satisfying requirements for IMT-2000 radio transmission technology (RTT). Additional requirements called for commercially effective evolution and deployment in TDMA networks:

- flexible spectrum allocation;
- high spectral efficiency;
- compatibility with TDMA;
- coverage equivalent to TDMA;
- support for macrocellular performance at high mobile velocities—in particular, the initial macrocellular deployment should not require more than 1 MHz of spectrum; and
- ability to coexist in the same spectrum with second-generation systems without degrading their performance.

After evaluating various proposals, the UWCC adopted EDGE, in January 1998, as the outdoor component of 136HS (later referred to as EGPRS-136) to provide 384 kbit/s data services. One argument in favor of this approach is that the same technology evolution can be leveraged for GSM and TDMA systems—which also facilitates global roaming. EDGE was thus included in the UWC-136 IMT-2000 proposal. In February 1998, this proposal was adopted by TR-45 and submitted by the US delegation to ITU as an RTT candidate for IMT-2000.[8] In November 1999, the proposal was approved as a radio-interface specification for IMT-2000. EDGE is currently being developed in two modes for TDMA systems: COMPACT and Classic.

COMPACT employs a new 200 kHz control-channel structure. Synchronized base stations are used to maintain a minimal spectrum deployment of 1 MHz in a 1/3 frequency-reuse pattern.

Classic employs the traditional GSM 200 kHz control-channel structure with a 4/12 frequency-reuse pattern on the first frequency.

EDGE is being developed concurrently in ETSI and the UWCC to guarantee a high degree of synergy in GSM and TDMA systems. The standardization roadmap for EDGE comprises two phases:

- Phase I emphasizes enhanced GPRS (EGPRS) and enhanced circuit-switched data (ECSD), which technologies were included in ETSI's 1999 release of the standard. Commercial products will follow in 2001.
- Phase II, which is being targeted for release in 2000, is currently being defined to include improvements for multimedia and real-time support.

EDGE and EGPRS

The GPRS packet-data system uses the same physical carrier structure as present-day GSM cellular communication systems and is designed to coexist with and provide the same coverage as GSM. The radio interface is based on the TDMA-structured GSM system with 200 kHz carriers divided into eight timeslots (TS) using Gaussian minimum-shift-keying (GMSK) modulation. In GPRS, each timeslot can typically serve several packet-data users, and users can be allocated more than one timeslot to increase data throughput.

The GPRS specification includes four coding schemes—which scheme is used depends on the quality of the radio carrier. With GPRS, it will be possible to obtain data rates well over 100 kbit/s.[9]

EDGE introduces higher level modulation and new coding schemes for packet-switched and circuit-switched data communication. In addition to GMSK modulation, EDGE introduces eight-symbol phase-shift-keying (8PSK) modulation. The symbol rates for GMSK and 8PSK are the same; that is, approximately 271 kilosymbols per second. The introduction of EGPRS increases maximum bit rates to approximately three times that of standard GPRS.

New techniques introduced with EDGE optimize the data throughput for each radio link. One such technique, called link quality control (LQC), combines link adaptation (LA) and incremental redundancy. The LA functionality adapts coding and modulation relative to signal quality. In poor radio conditions, robust coding and GMSK modulation are selected, whereas in good radio conditions, less robust coding and 8PSK modulation are employed. EGPRS also features backward error-correction functionality,

TABLE 1. MODULATION AND CODING SCHEMES FOR EGPRS

Scheme	Modulation	Maximum rate [kbit/s]	Code rate	Header code rate	Family
MCS-9	8PSK	59.2	1.0	0.36	A
MCS-8	8PSK	54.4	0.92	0.36	A
MCS-7	8PSK	44.8	0.76	0.36	B
MCS-6	8PSK	29.6	0.49	1/3	A
MCS-5	8PSK	22.4	0.37	1/3	B
MCS-4	GMSK	17.6	1.0	0.53	C
MCS-3	GMSK	14.8	0.80	0.53	A
MCS-2	GMSK	11.2	0.66	0.53	B
MCS-1	GMSK	8.8	0.53	0.53	C

which means that it can request the retransmission of erroneously received blocks. This mechanism is called automatic repeat request (ARQ). EGPRS uses an enhanced variant of ARQ called incremental redundancy (IR). With IR, all information is coded with a convolution code at a rate of 1/3. The code is punctured to a certain rate and transmitted over the air. If the decoding fails, a retransmission is formed using a different puncturing scheme. Because the retransmission is combined with the previously transmitted block, the process yields a lower bit rate, which facilitates decoding. At present, nine coding schemes have been defined for EGPRS, see Table 1.

The "Family" column in Table 1 indicates the coding schemes that can be used for retransmission. For example, if the initial transmission with MCS-9 fails and the quality of the radio channel diminishes, the retransmission can use more robust coding schemes from the same family.

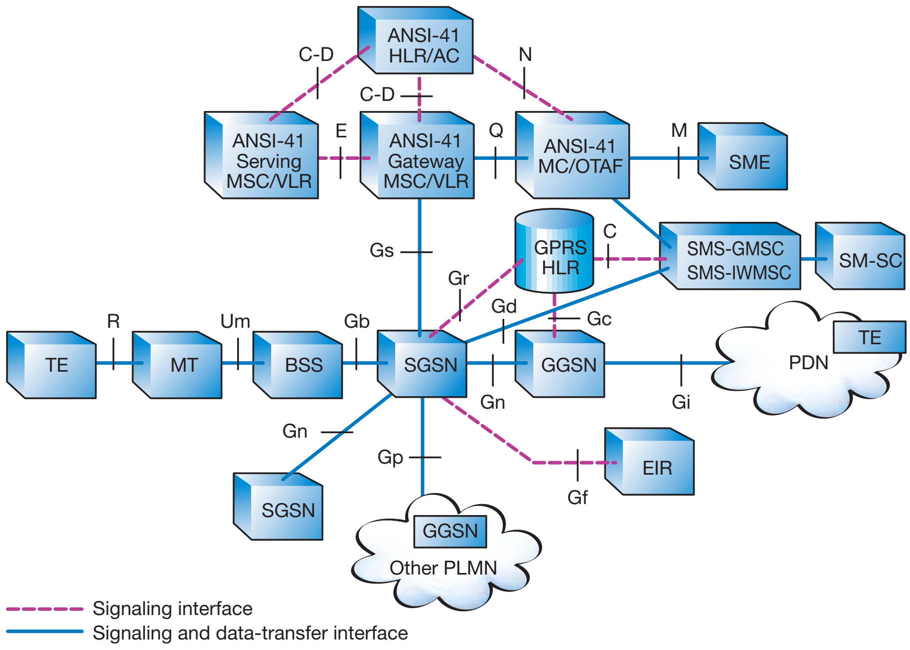
Had the retransmission used a different coding scheme than the original transmission, then it would have to be resegmented into new radio link control (RLC) blocks. This is what limits the selection of coding schemes. Blocks that are initially transmitted with MCS-8 can be retransmitted using MCS-6 or MCS-3, by adding padding bits to the data field.

It should also be noted that even when there is nothing with which to combine a retransmission—that is, if the initial transmission is lost altogether—it is nonetheless possible to decode a retransmission. There is flexibility in the implementation of LQC for EGPRS in the system: LA will be mandatory, while IR is optional.

GPRS in TDMA systems —system architecture

The packet core network for COMPACT and Classic, which is based on the core network architecture for GPRS networks, is integrated with TIA/EIA-136 circuit-switched networks via a serving GPRS support node (SGSN). Figure 1 shows the reference model for the resulting network.

Figure 1
Reference model for an EGPRS-136 network integrated into a TIA/EIA-136 circuit-switched network through an SGSN gateway MSC/VLR.



"*Gs*" is the interface between the ANSI-41 MSC/VLR and the SGSN. This interface has been extended to include the tunneling of non-GSM messages, which enables the transparent transmission of TIA/EIA-136 signaling messages between the mobile terminal and the MSC/VLR through the EGPRS-136 packet-data network. The signaling messages are transported using the tunneling-of-messages (TOM) protocol layer (Figure 2). This protocol layer uses logical link control (LLC) unacknowledged-mode procedures to tunnel messages between the mobile terminal and the SGSN. Between the SGSN and the MSC/VLR, the messages are transported using an enhanced base station system application part (BSSAP+) protocol.[10]

For cell selection, terminals that support 30 kHz circuit-switched services scan for a 30 kHz digital control channel (DCCH) according to TIA/EIA-136 procedures. If an acceptable 200 kHz EGPRS-136 system exists, a pointer to this system will be available on the 30 kHz DCCH. On finding the pointer, the terminal leaves the 30 kHz system and begins initiating access to the EDGE system. The terminal starts its initial scanning of 200 kHz carriers according to information in the pointer. When it finds the 200 kHz control carrier, the mobile terminal behaves much the same as a GSM/GPRS terminal would.

With the circuit system, locations are updated using the TOM protocol for transmitting a registration message to the MSC/VLR. When an incoming circuit-switched call arrives for a certain mobile terminal, the gateway or serving MSC/VLR associated with the latest registration initiates circuit-switched paging—either a hard page (circuit voice page without additional parameters but with small delay) or a transparent layer 3 page (to which additional information can be added; this page introduces more delay than the hard page). For a hard page, the *Gs* interface paging procedures are used by the MSC/VLR and the SGSN. For a layer 3 page, the TOM protocol is used. To answer a circuit-switched page, the mobile terminal suspends packet-data traffic (if any) and starts looking for a 30 kHz DCCH. The 200 kHz broadcast information provides mobile terminals with a list of DCCH carriers. Mobile terminals that only support 200 kHz immediately search for a 200 kHz carrier and solely register in the 200 kHz packet-data system.

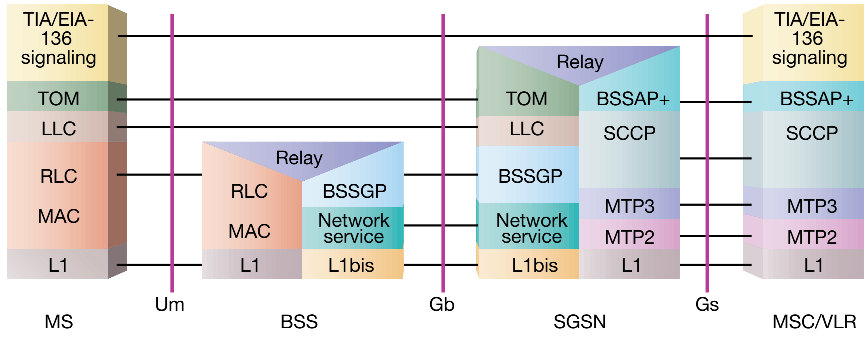


Figure 2
Protocol stack for an EGPRS-136 network and a TIA/EIA-136 circuit-switched network.

Classic

The Classic system uses standard GSM carriers and control channels. Thus, Classic can be deployed using, for example, 12 carriers allocated in a 4/12 frequency-reuse pattern. The carriers provide data traffic and all necessary control signaling according to the GSM/GPRS standard with EDGE additions being finalized in ETSI.

One timeslot on the first carrier is used for control signaling. The structure of the control channel, which is basically identical to GSM control channels and transmitted in a 51 multiframe structure[11], accommodates all necessary control signaling on the 200 kHz carriers. The network supplies interconnection with the TDMA system for circuit-switched paging and functions that relate to mobility management.

Classic can be extended to include additional 200 kHz carriers that carry either control channels or pure packet-data channels and associated signaling or combinations thereof. These carriers can be introduced in a 1/3 frequency-reuse pattern, which means that capacity can be increased significantly. The control channels, however, are not used in a 1/3 frequency-reuse pattern.

COMPACT

Thanks to link quality control, EGPRS can be introduced in a tight frequency plan and still provide high data rates for packet-data services. The COMPACT system can be deployed using only 600 kHz of spectrum. Al-

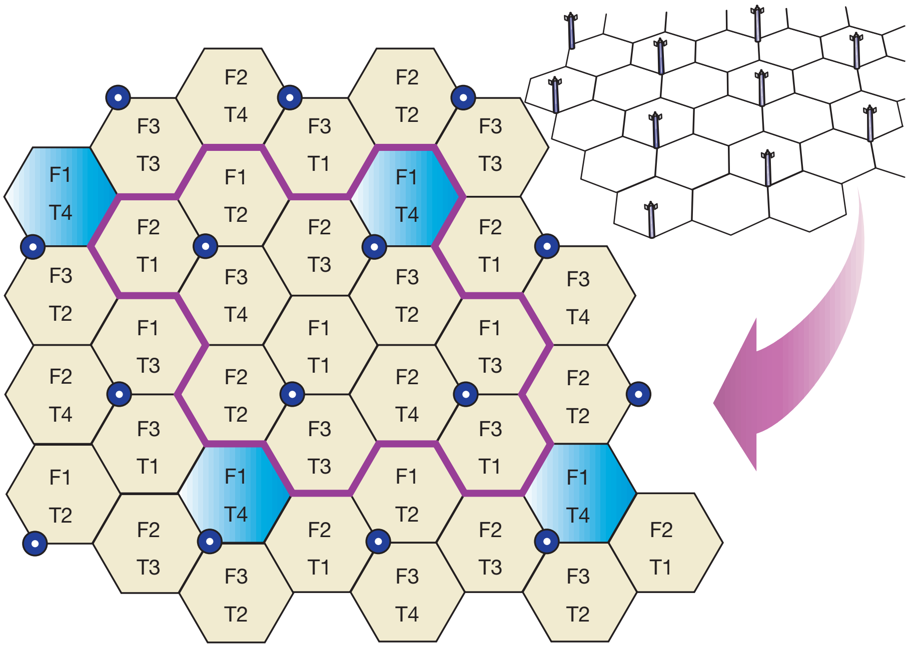


Figure 3
An example of a cell pattern for a 4/12 time and frequency-reuse pattern.

though the radio network uses three carriers in a 1/3 frequency-reuse pattern, it achieves an effective 3/9 or 4/12 frequency-reuse pattern for the control channels by employing time groups obtained through the synchronization of base stations.

The three carriers carry data traffic, packet-associated signaling, and packet common control signaling according to the GPRS standard with EDGE additions. The synchronization of base stations makes it possible to allocate packet common control channels and packet broadcast control channels in a way that prevents simultaneous transmission in the cluster. Thus, it creates an effective reuse for control signaling of, say, 3/9 or 4/12. Synchronization is required at the symbol level and can be achieved by means of global positioning system (GPS) receivers.

Each base-station sector is assigned one time group. A different time group is used in a neighboring site sector that uses the same frequency. Figure 3 illustrates the distribution of frequencies and time groups over cells and sectors.

COMPACT includes modifications of all packet common control channels defined for GPRS, including

- COMPACT packet paging channel (CPPCH);
- COMPACT packet access-grant channel (CPAGCH);
- COMPACT packet random-access channel (CPRACH);
- COMPACT packet broadcast channel (CPBCCH); and
- packet timing-advance control channel (PTCCH).

The packet-data traffic channels (PDTCH) and packet-associated control channels are identical to those defined for Classic.

Different time groups share the same frequency, but split the timeslots for control signaling. Figure 4 shows multiframe structures for an effective 4/12 frequency-reuse pattern. The 52 multiframe structure is illustrated.

The time-group division between sites does not affect the timeslots and blocks that carry data traffic; that is, the data traffic continues to employ a 1/3 frequency-reuse pattern. It should be noted, however, that blocks which coincide with a neighboring site's control block using another time group are not used. In Figure 4, these blocks are shaded. If an effective 3/9 frequency-reuse pattern is employed for control signaling, only three time groups are used with control blocks.

The number of blocks allocated for CPBCCH and CPCCCH is flexible—from 4 to

12 blocks per timeslot in each 52 multiframe.[11] Figure 4 shows a feasible block configuration, where one block is allocated for CPBCCH and three blocks for CPCCCH.

A synchronization burst designed for COMPACT, called the COMPACT SCH, or CSCH, features unique coding of the frame numbers, an indication of time group, and an extended training sequence. This burst is transmitted in the last GSM frame of every 52 multiframe. The COMPACT frequency correction channel (CFCCH) is allocated in GSM frame 25. The bit pattern of the CFCCH differs from the frequency correction channel (FCCH) found on the broadcast control channel (BCCH) carrier in GSM.

System performance

General assumptions

The simulations described in this article assume that 6.67 TS are available for traffic in the COMPACT mode (1/3 frequency-reuse pattern). This corresponds to four blocks allocated for CPBCCH and CPCCCH in an effective 4/12 frequency-reuse pattern. The Classic mode has 7 TS available for traffic (4/12 frequency-reuse pattern)—one timeslot is always assigned for broadcast and common control. Table 2 summarizes certain basic characteristics of the two modes. The simulations described share the following assumptions:

- EDGE radio interface with incremental redundancy.
- The channel model used is *ETSI typical urban for 3 km/h* (TU3).
- No frequency hopping—minimum deployment is emphasized and only one carrier is used per sector.
- Downlink—due to asymmetrical usage, the downlink is anticipated to be the restricting link for packet data. The uplink performance is expected to be similar to that of the downlink.
- No receiver antenna diversity in the mobile terminal.

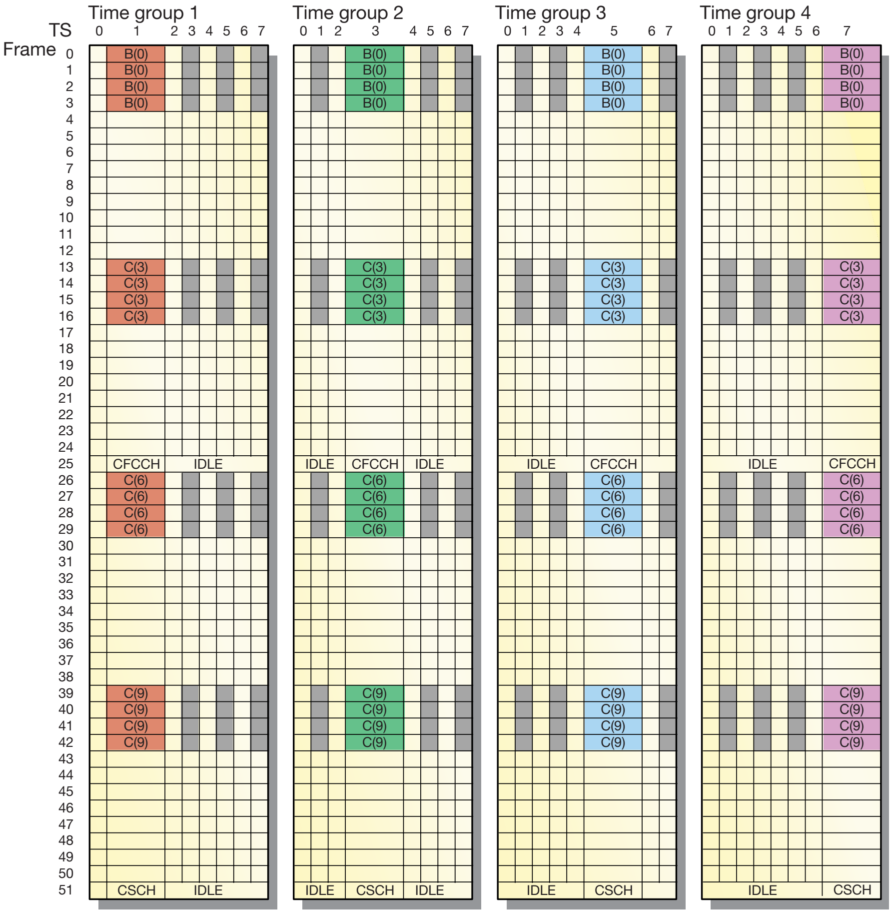


Figure 4
A 52 multi-frame structure showing 4 time groups. *B(0)* shows the position of CPBCCH whereas *C(i)* is the position of CPCCCH in block *i*.

TABLE 2. SOME BASIC CHARACTERISTICS FOR CLASSIC AND COMPACT

Classic Mode	**COMPACT Mode**
• All control and packet traffic channels on 200 kHz	• All control and packet traffic channels on 200 kHz
• 4/12 reuse	• 1/3 reuse
• 2.4 MHz + guard band	• 0.6 MHz + guard band
• No requirement for synchronized BS	• Synchronized BS providing 4/12 reuse for PBCCH, PCCCH, PSCH, PFCCH
• 7 TS available for traffic	• 6.67 TS available for traffic
• Carrier transmits constantly	• No transmission in idle slots

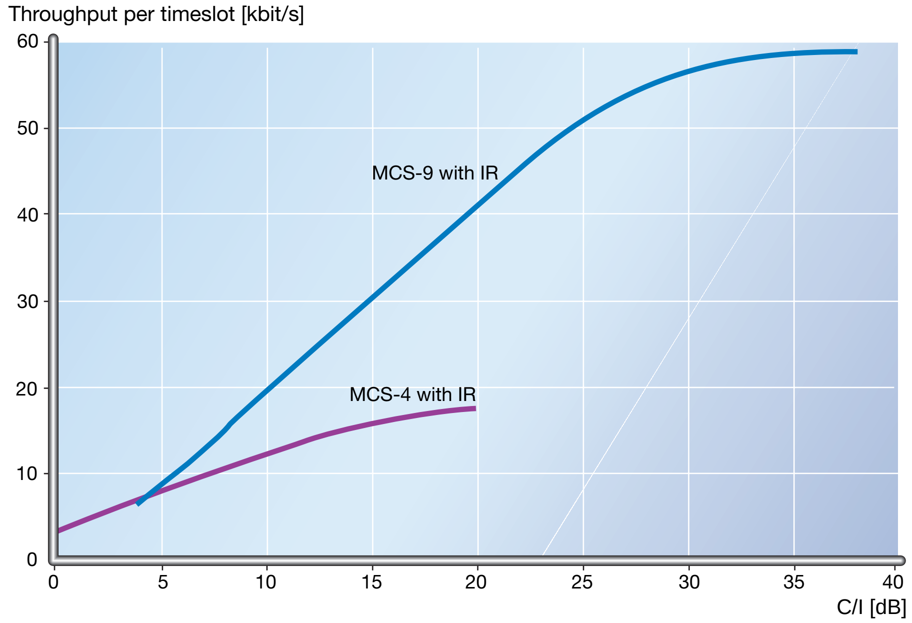


Figure 5
Curves illustrating maximum data throughput for MCS-4 and MCS-9 versus C/I.

EDGE radio-link performance

EDGE radio-link performance has been evaluated extensively by ETSI and UWCC. Figure 5 shows the throughput for one timeslot as a function of the carrier-to-interference ratio (C/I). The throughput is obtained from simulations of the IR LQC scheme. This radio-link simulation creates the basis for all subsequent system simulations described in this article.

Static system-level simulations

Figure 6 shows the maximum performance of EDGE packet traffic channels for different frequency-reuse patterns (maximum in the sense that channel utilization is 100% and all 8 TS are used for traffic). The results are based on static system-level simulations and the radio-link simulations mentioned above. As expected, a tighter frequency-reuse pattern with higher interference reduces mean throughput per carrier. What is interesting, however, is that the spectral efficiency of EDGE increases with tighter frequency reuse (that is, the smaller bandwidth required by tighter frequency reuse outweighs the reduction in throughput). This confirms EDGE´s capacity to perform well in situations characterized by high interference, such as in a 1/3 frequency-reuse pattern.

One way of analyzing the system performance of a packet-data network is to study the average throughput per carrier. Figure 7 shows the impact of channel utilization (traffic intensity) on this metric on the first carrier. The results are based on static system-level simulations and the radio-link simulations described above, with 7 TS used for Classic and 6.67 TS for COMPACT data traffic. As can be seen, performance in Classic mode with one carrier per sector does not depend on traffic load. This is because the carrier transmits constantly; that is, channel utilization on the first carrier is always 100%. As expected, average throughput in COMPACT mode for a particular carrier de-

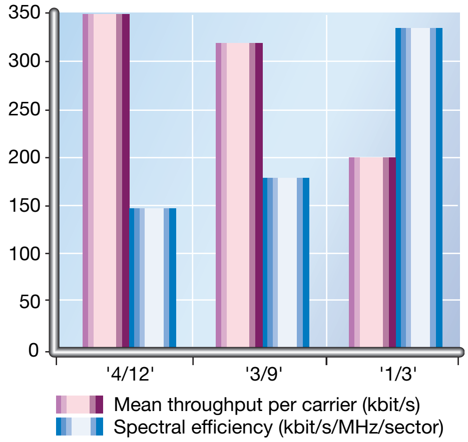


Figure 6
Carrier throughput and spectral efficiency for three different frequency-reuse patterns.

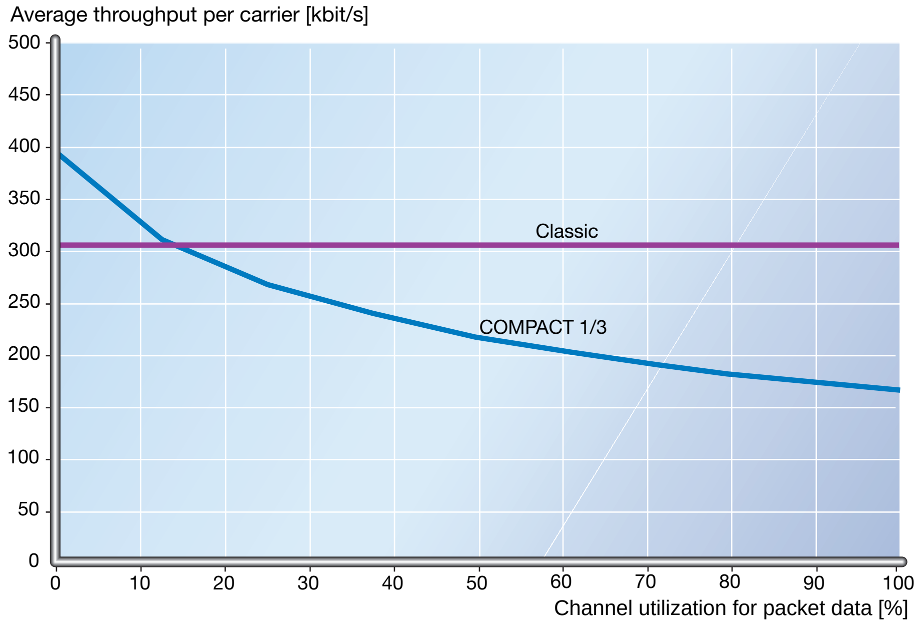


Figure 7
Carrier throughput versus channel utilization for the first carrier using Classic and COMPACT.

creases with increased traffic load. Figure 8 shows the maximum spectral efficiency and average throughput on the first carrier for the different modes. Maximum spectral efficiency is obtained when channel utilization is 100%, which means that all capacity for packet traffic is used. The data capacity for COMPACT is 6.67 TS; for Classic, 7 TS.

If a second carrier is added, it can carry traffic on all 8 TS for both modes, typically in a 1/3 frequency-reuse pattern. As seen in Figure 9, throughput for an additional carrier depends on system load, for COMPACT as well as Classic.

Dynamic packet-data system simulations

It is easier to evaluate the system performance (simulation) of a packet-data network if the traffic in the system is generated dynamically. The results discussed below are based on dynamic simulations of packet-data traffic where a large number of terminals are studied over a period of time.[6] A packet traffic model for Web-browsing traffic is used.[12] Table 3 summarizes the parameters used in the dynamic simulations.

Figure 10 shows the number of users that can be served while guaranteeing the quality-of-service (QoS) limit of 90% of the packets. The results are obtained with dynamic packet-data system simulations and the radio-link simulations described above with 7 TS used for data traffic both for COMPACT and Classic. As seen from Figure 10, 10% percentile of packet throughput is plotted against the average number of users per sector. The QoS limit is 10% of the available peak bit rate. COMPACT can handle about 30 users per sector, whereas Classic can handle 60 users per sector.

It is also interesting to study the distribution of user throughput, and not just the 10% percentile of packet throughput. Figures 11 and 12 show the cumulative distri-

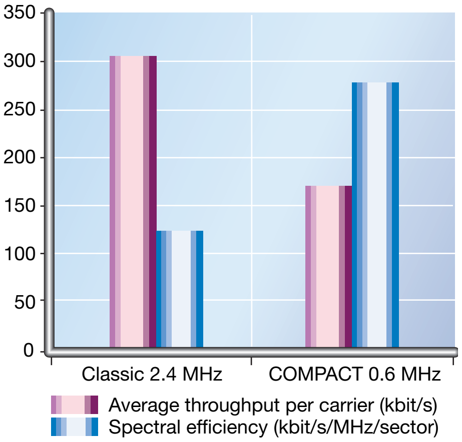


Figure 8
Throughput and spectral efficiency for the first carrier in Classic and COMPACT.

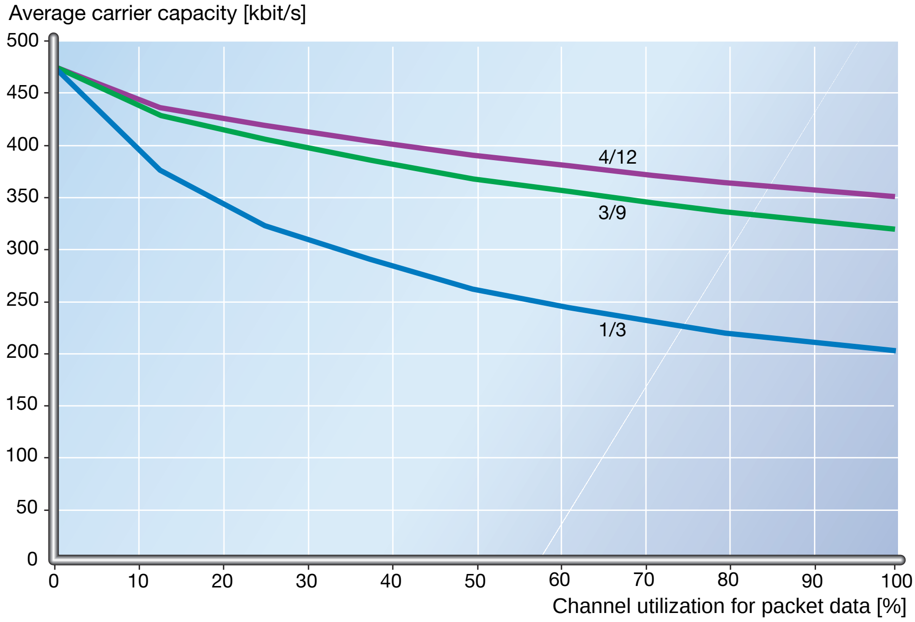
TABLE 3. DYNAMIC PACKET DATA SIMULATION PARAMETERS

Time step	20 ms
Mobility	No
Multislot allocation	No
Power control	No
Admission control	No
Packet scheduling	FIFO
User dropping	Yes, according to a leaky bucket algorithm (less than 1%)
User arrivals	Poisson process
Packet traffic model:	Web browsing:
• Number of packets per user	• Geometrical distribution mean of 10 packets
• Time between packets	• Pareto distribution mean of 10 seconds pareto shape parameter 1.4
• Packet size	• Log-normal distribution mean of 4.1 kbytes

bution function (CDF) of user throughput during a Web-browsing session for Classic and COMPACT modes. Since the simulations do not model multislot allocation, user throughput on the x-axis is for one timeslot. To obtain a rough estimate of the corresponding distribution for 7 TS, we can multiply the values on the x-axis by seven. A multislot allocation scheme, however, will provide an improvement of the actual distribution that is not captured by such simplistic scaling. When the systems are loaded to capacity as defined by the QoS limit on packet throughput, user throughput is still high. In the COMPACT system, 90% of the users obtain throughput that exceeds 12 kbit/s per timeslot with 30 active Web-browsing sessions on the first carrier. Similarly, in the Classic system, 90% of the users obtain throughput exceeding 17 kbit/s per time-slot with 60 active Web-browsing sessions.

Finally, a look at spectrum efficiency for the two modes (Figure 13) shows that even though COMPACT handles about half as many users per sector as Classic, it has twice the spectrum efficiency, thanks to a slimmed bandwidth of 0.6 MHz.

Figure 9
Carrier throughput versus channel utilization for three different frequency-reuse patterns.



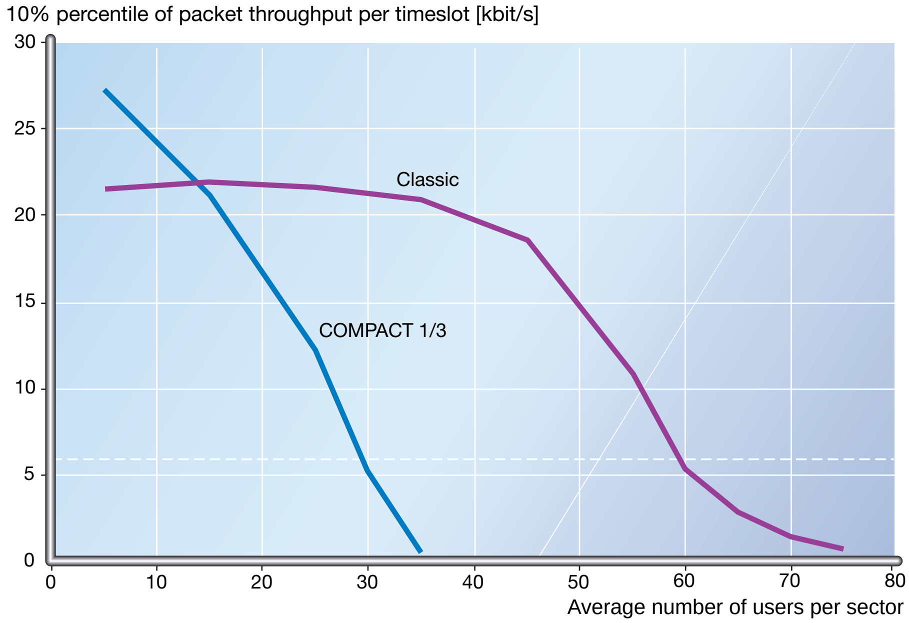


Figure 10
10% percentile of packet throughput per timeslot versus number of users. Note: 90% of the packets have higher throughput.

Coverage

One requirement put on EGPRS-136 is that to enable an introduction in present-day cell plans and using existing base stations, the coverage it provides must equal or surpass that of TDMA. EGPRS with link quality control satisfies this requirement. Indeed, thanks to link quality control, poor radio-link quality does not cause packet calls to be dropped, but only reduces the user bit rate.

A static simulation technique can be used in coverage-limited cases, since performance does not depend on interference or traffic dynamics. Snapshots of the system are taken, in which stationary mobile terminals are placed randomly according to a uniform distribution. To determine what kind of cov-

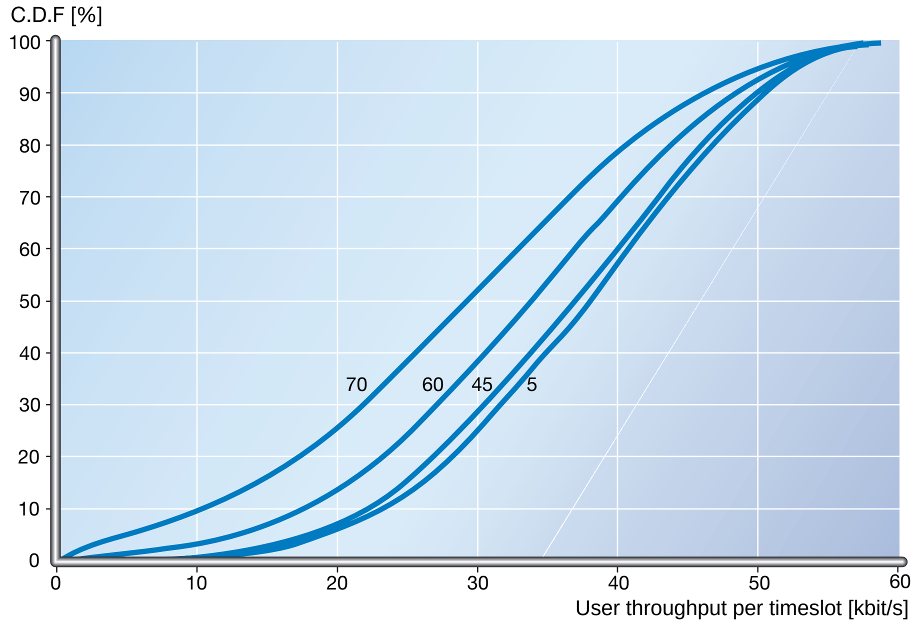


Figure 11
CDF of user throughput per timeslot for Classic, 4/12 frequency-reuse pattern with 5, 45, 60 and 70 users per sector.

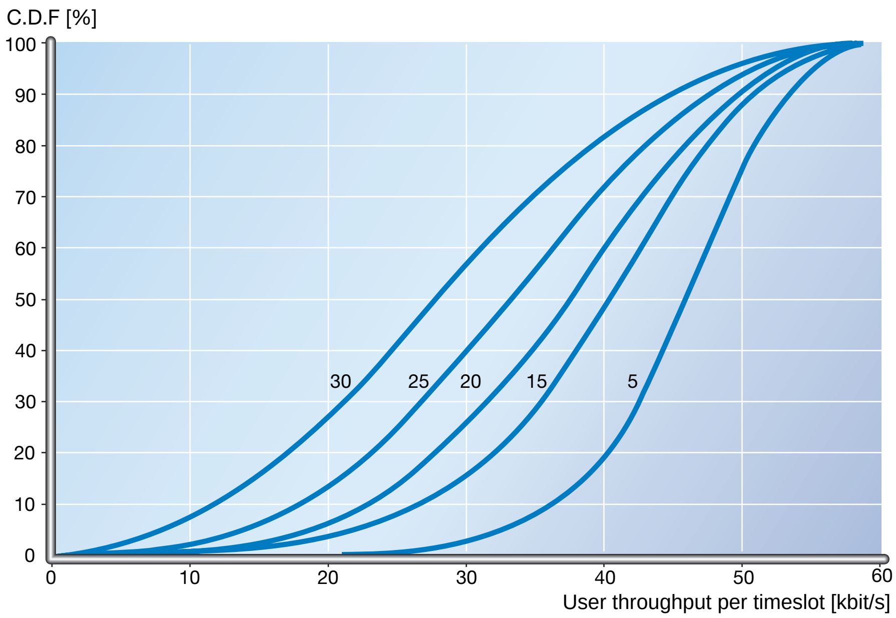
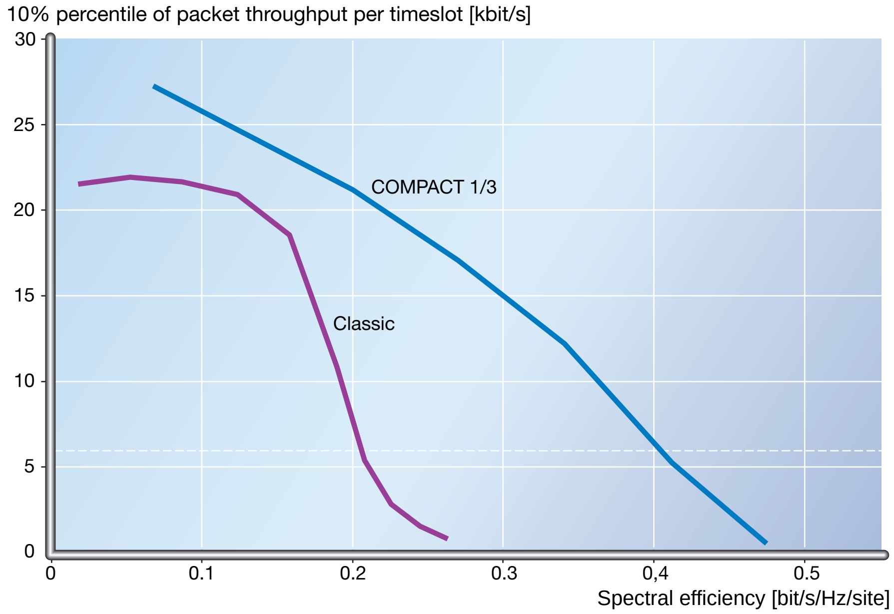


Figure 12
CDF of user throughput per timeslot for COMPACT, 1/3 frequency-reuse pattern with 5 to 30 users per sector.

Figure 13
10% percentile of packet throughput per timeslot versus spectral efficiency for Classic and COMPACT.



erage can be achieved in existing cell plans, a TDMA system with 95% voice coverage is used as reference. With this reference, the results are valid for the downlink. EDGE performance is analyzed assuming the same carrier output power as in the reference system. Additionally, within EGPRS, the same average power is assumed for GMSK and 8PSK. For TDMA, the requirement is an E_b/N_0 of 15.7 dB. Thus, this is the value found at the 5% percentile of E_b/N_0 distributions in the cell. When the 8PSK EDGE modulation scheme is introduced, the E_b/N_0 distributions diminish due to the higher gross bit rate. Assuming the same carrier output power, the difference in E_b/N_0 for EDGE compared to that of standard TDMA modulations is calculated as

$$\Delta E_b = \frac{R_{TDMA}}{R_{EDGE}} = \frac{48.6 \text{ kbit/s}}{3 \cdot 271 \text{ kbit/s}} = -12.2 \text{ dB}$$

where R_{TDMA} and R_{EDGE} are the gross rates of standard TDMA and EDGE, respectively.

The coverage simulations result in E_b/N_0 distributions. From these original distributions, we can calculate distributions for 8PSK. Additionally, we can determine the block error-rate performance of different modulation and coding schemes from the radio-link-level simulations for the downlink with noise but without interference (E_b/N_0). The results do not include antenna diversity; similarly, body loss is neglected for packet-data traffic. Given the performance results derived from the block-error rate, we can transform the E_b/N_0 distribution into a packet-bit-rate distribution, using an E_b/N_0 curve, which is similar to the C/I curve in Figure 5.

Assuming a system with 95% TDMA voice coverage, then EDGE coverage is excellent (Figure 14). Approximately 95% of the users obtain a packet bit rate that exceeds 120 kbit/s using 7 TS. Existing sites can thus be reused with excellent performance. Even better coverage can be achieved by employing smart antennas or antenna-diversity techniques.[13-14]

Terminal capabilities

GPRS and EGPRS terminals can support different modes of operation. For example, the GSM/GPRS standard for pure 200 kHz use specifies class B and class C modes of operation. In the class B mode of operation, a mobile terminal can be attached to GPRS and other GSM services simultaneously, but can only operate one set of services at a time. In the class C mode of operation, the mobile terminal can attach to either GPRS or other GSM services but not both. According to these definitions, mobile terminals will be made available for class B136 and C136 modes of operation, with a 200 kHz GPRS-based packet-data mode and a TIA/EIA-136 30 kHz-based circuit-switched mode. The COMPACT and Classic systems accommodate the class B136, C136, and pure 200 kHz class C (GPRS) modes of operation.

Conclusion

The TDMA and GSM systems have chosen the same EDGE radio-access and GPRS packet-switched core network technologies to provide third-generation services in existing spectrum. Accordingly, a common access for data services can be offered to more than 370 million mobile subscribers.

EDGE can be deployed in two modes in TDMA systems: Classic and COMPACT. The Classic system requires only minimum extension to GSM EDGE and uses standard GSM/GPRS control channels, which facilitates global roaming.

The COMPACT system introduces a novel control channel configuration, synchronized base stations, and discontinuous transmission on the first carriers, which facilitates the deployment of EDGE control channels in a 1/3 frequency-reuse pattern. Thus, the initial deployment of COMPACT requires only a very limited amount of spectrum—600 kHz plus guard bands. With fractional loading, excellent spectral efficiency can be attained with data rates of up to 384 kbit/s. COMPACT thus supports UWCC requirements for third-generation services with high spectral efficiency and initial deployment within less than 1 MHz of spectrum.

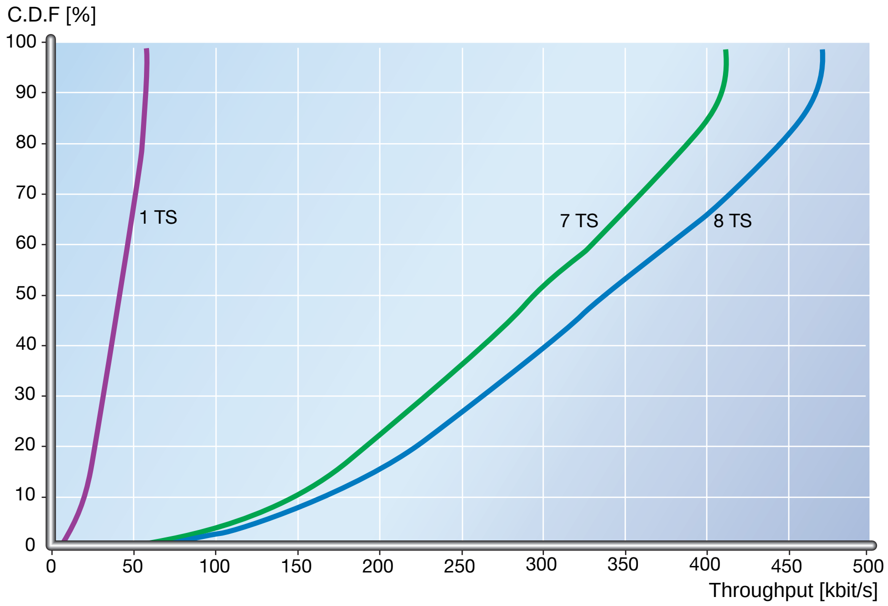


Figure 14
Throughput CDF in a coverage-limited system.

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