SPECIAL TOPIC

TD-SCDMA HSUPA Technology

Abstract:
The High Speed Uplink Packet Access (HSUPA) technology for Time Division-Synchronous Code Division Multiple Access (TD-SCDMA) is used to improve the overall uplink performance: to increase the peak data rate and throughput and to reduce the transmission delay of uplink. The considered enhancements include Adaptive Modulation and Coding (AMC), Hybrid Automatic Repeat Request (HARQ), Node B fast scheduling and sharing of uplink channel resources between User Equipments (UE). New Media Access Control protocol entities (MAC-e and MAC-es) are adopted to enhance and optimize protocols. Simulation results of these technologies show that the system performance (including the peak rate, throughput, and delay) can be improved significantly.

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With the rapid development of mobile communications and the Internet, more and more data services, such as video clipping, stream media and downloading, emerge. These services require increasing data rate and throughput and reducing delay, putting forth higher requirements for the mobile communication system. To meet the increasing demand for packet data services, 3rd Generation Partnership Project (3GPP), has proposed and standardized the High Speed Downlink Packet Access (HSDPA) protocol, which is the main feature of 3GPP Release 5 (both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) are included). The research and standardization of HSDPA enable the downlink performance of 3G systems to be greatly improved. This raises a question: can the technologies for HSDPA be used in the uplink packet services to optimize the uplink performance, for instance, coverage, throughput and delay? To answer this question, 3GPP first focused its research on High Speed Uplink Packet Access (HSUPA) technologies, and set up the work item for feasibility study on uplink enhancement for Wideband Code Division Multiple Access (WCDMA) FDD. Then the TDD equipment vendors proposed the work items for TDD uplink enhancement to evaluate such technologies as Node B fast scheduling, Adaptive Modulation and Coding (AMC) and Hybrid Automatic Repeat Request (HARQ)[1-2]. As an important part of the 3GPP, Time Division-Synchronous Code Division Multiple Access (TD-SCDMA) working group has also done much research and evaluation on HSUPA. Following technical evaluation, the working group has began the work item for TD-SCDMA HSUPA, mainly to make the specific standards based on the feasibility study, including uplink channel structure definition, signaling and physical layer processing. At present, this work item is still in progress. In this article, the key technologies used in TD-SCDMA HSUPA, as well as the issues to be taken into account in standardization, will be covered.

1 Key TD-SCDMA HSUPA Technologies

The enhancement of uplink for TD-SCDMA is used to increase the peak data rate and throughput, to reduce traffic delay, and to decrease the Frame Error Rate (FER). Like HSDPA, HSUPA will adopt such technologies as AMC, HARQ and Node B fast scheduling, and pay much attention to the way User Equipment (UE) shares uplink channel resources. In terms of uplink resources sharing, there is a difference between FDD and TDD. For FDD, the High Speed Downlink Shared Channel (HS-DSCH) of HSDPA is shared by users while in HSUPA, each user has its own data link connected to Node B, that is, each user has its own channel resources. The reason for this difference is that a TDD system uses a cell-specific scrambling sequence to identify each cell, which results in limited uplink code resources. For TD-SCDMA, the uplink enhancement is based on resource sharing.

The principles of AMC, HARQ and Node B fast scheduling in TD-SCDMA HSUPA are similar to those in FDD HSUPA, and they will not be discussed here. The focus of this article will be on the analysis of using these technologies to fulfill TD-SCDMA uplink enhancement.

1.1 Node B Fast Scheduling

Node B fast scheduling can bring

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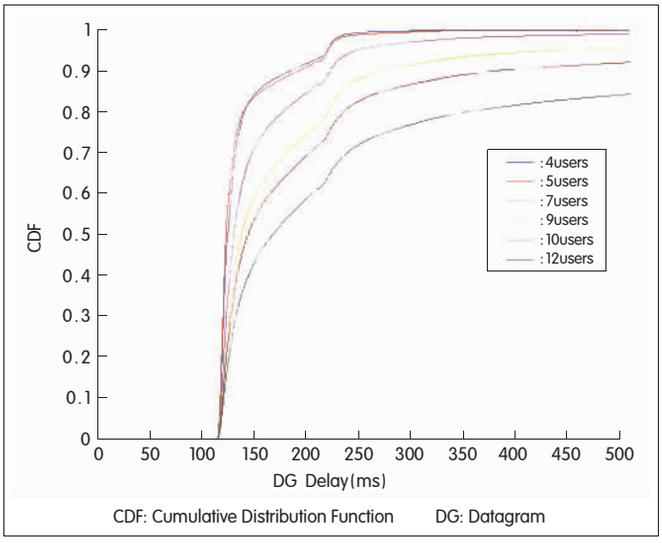
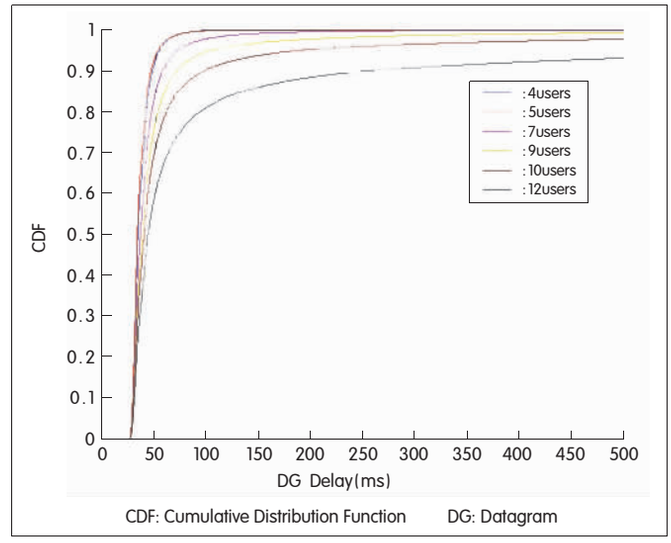


▲Figure 1. DG delay CDF, RNC (3GPP Release 5) scheduling (a modified gaming model and round robin scheduler (8 antennae) are used).

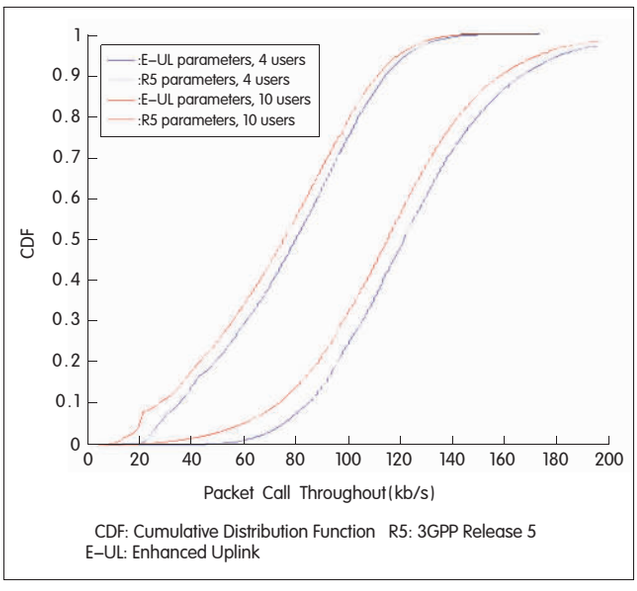


▲Figure 2. DG delay CDF, Node B (Enhanced-Uplink) scheduling (a modified gaming model and round robin scheduler (8 antennas) are used).

reduced traffic delay and improved throughput. The reason is that the transmission process at the Iub interface is shortened, and that retransmission/UE buffer volume measurement are responded quickly compared to RNC scheduling. These benefits of Node B fast scheduling can be verified with simulations.

Figures1 and 2 are simulation results of delays using Radio Network Controller (RNC) scheduling and Node B scheduling, respectively. Suppose 99% of Datagrams (DG) should experience a delay of less than 250 ms, in R5 (i.e., RNC scheduling), five UEs are supported, but in HSUPA (i.e., Node B scheduling), up to nine UEs can be supported, meaning that there is an increase of 80% in the number of UE supported.

Figure 3 is the simulation result of throughputs using Node B scheduling and RNC scheduling. Compared to RNC scheduling, Node B scheduling increases the throughput of packet services by approximately 50%. Further analysis shows the throughput gain is more significant for those packet services with short packet call duration, as short delay has a greater effect on them.



▲Figure 3. Packet call throughput CDFs at low and high loading (a modified gaming model is used, and 500 ms is the packet call duration (8 antennae)).

In addition to traffic delay and throughput, TD-SCDMA system can benefit from Node B scheduling in resources allocation and interference control. As the TDD uplink code resources are limited, the sharing and fast scheduling of physical resources can mitigate the limitation situation and quickly adapt the system to the changing radio conditions. Besides, by fast control over UE's transmission rate, the base station (Node B) can better control the interference at the air interface.

1.2 AMC

As a link adaptive technology, AMC can increase the system capacity by means of adopting higher order modulation method for good radio condition. Here, simulation analyses regarding the effect of the modulation schemes on the system performance and UE Power Amplifier (PA) are given.

In terms of the effect on system performance, the simulations are performed for three modulation cases:

- Case 1: Quadrature Phase-Shift Keying (QPSK) only
- Case 2: QPSK and 8 Phase-Shift Keying (8PSK)
- Case 3: QPSK, 8PSK and 16-order Quadrature Amplitude Modulation (16QAM)

Figure 4 shows the relationship between sector throughput and noise rise. It can be seen here that the throughput in Case 3 is increased by 14% to 18% and 54% to 56% compared to Cases 1 and 2, respectively.

On the uplink, the Peak to Average Power Ratio (PAR) is, among others, an important issue that has to be taken into account. Therefore, the effect of higher

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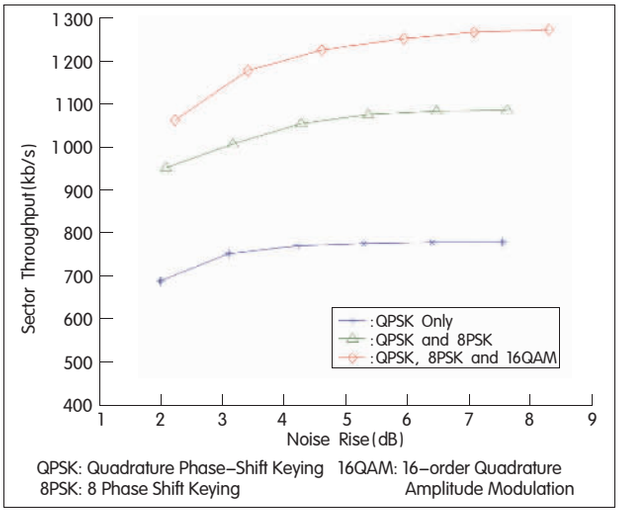

◀Figure 4. The relationship between sector throughput and noise rise in three modulation modes (4 uplink timeslots, 8 antennas).

▼Table 1. UE PA backoffs in three modulation modes for different OVSFs

OVSF Resource	Modulation	UE PA Backoff
1 × SF16	QPSK	2.3 dB
2 × SF16	QPSK	4.7 dB
3 × SF16	QPSK	6.1 dB
1 × SF16	8PSK	2.3 dB
2 × SF16	8PSK	4.6 dB
3 × SF16	8PSK	5.9 dB
1 × SF16	16QAM	4.4 dB
2 × SF16	16QAM	6.8 dB
3 × SF16	16QAM	7.3 dB
1 × SF8	QPSK	2.4 dB
2 × SF8	QPSK	4.9 dB
3 × SF8	QPSK	5.7 dB
1 × SF8	8PSK	2.4 dB
2 × SF8	8PSK	4.8 dB
3 × SF8	8PSK	5.6 dB
1 × SF8	16QAM	4.5 dB
2 × SF8	16QAM	6.6 dB
3 × SF8	16QAM	7.0 dB

8PSK: 8 Phase-Shift Keying
16QAM: 16-order Quadrature Amplitude Modulation
QPSK: Quadrature Phase-Shift Keying
OVSF: Orthogonal Variable Spreading Factor
SF: Spreading factor

order modulation on UE PA backoff is analyzed here. Table 1 is a summary of UE PA backoffs in the three modulation modes for different Orthogonal Variable Spreading Factors (OVSF).

The result indicates that 8PSK can deliver a slightly lower PAR than QPSK for the same number of OVSF codes; for 16QAM, the PAR is 2.1dB higher than that of QPSK.

1.3 HARQ

Like HSDPA, HSUPA uses HARQ to rapidly retransmit the erroneously received data and reduce the Radio Link Control (RLC) retransmissions, thus improving the quality of services experienced by end users. The two main aspects involved in adopting this technology are traffic delay and system throughput. As HARQ has impacts on the physical and Medium Access Control (MAC) layers, other factors, such as memory requirement of Node B and UE, signaling load, complexity, and UE power limitation, should also be taken into account.

Figure 5 shows the average number of transmissions in Pedestrian A Channel at 3km/h (PA3) with and without Chase combining. It can be seen that at a low Carrier-to-Interference Ratio (C/I), the use of Chase combining allows the number of transmissions to fall significantly.

The analyses or evaluations of the above-mentioned technologies were made during the feasibility study of TD-SCDMA HSUPA, and in the standardization of TD-SCDMA HSUPA that followed; it is suggested that these techniques be applied in TD-SCDMA HSUPA.

2 TD-SCDMA HSUPA Standard

2.1 E-DCH Channel

To support the HSUPA characteristics, the Enhanced Dedicated Channel (E-DCH) is introduced in the TD-SCDMA system to carry the high speed uplink data. The Transmission Time Interval (TTI) of this channel is 5ms, and it supports higher order modulation and Layer 1 (L1) HARQ process. The resources the channel used, including power, time slots and code resources, are all allocated by Node B. Meanwhile, two other control channels, E-DCH Uplink Control Channel (E-UCCH) and E-DCH Random Access Uplink Control Channel (E-RUCCH), are introduced to send the signaling messages related to uplink enhancement. E-UCCH is often multiplexed with E-DCH to transmit the message related to E-DCH HARQ; E-RUCCH is mapped onto the physical random access resources to send the access request of uplink enhancement

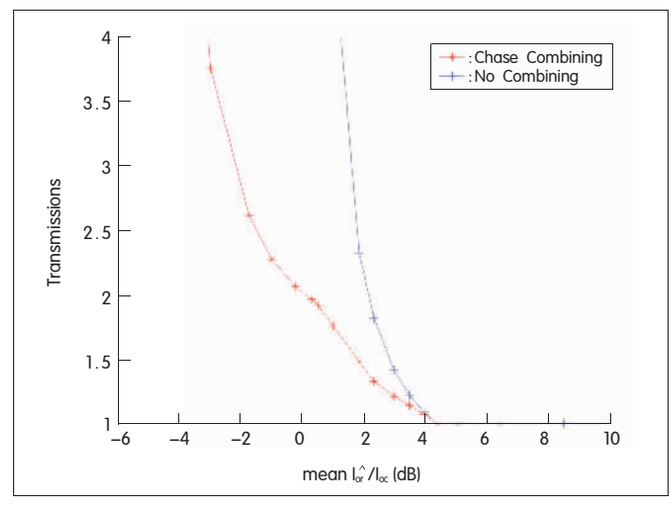

Figure 5.▶ Average number of transmissions in a PA3 with power control.

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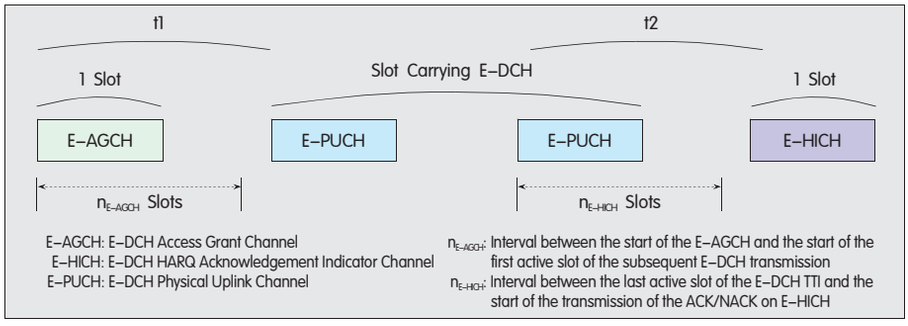

▲Figure 6. HARQ timing relationship.

services while E-DCH is mapped onto the E-DCH Physical Uplink Channel (E-PUCH). The E-PUCH channel resources fall into two categories: scheduled and non-scheduled. The non-scheduled E-PUCH resources are allocated by the RNC, but the scheduled ones are allocated and scheduled by the Node B MAC-e entity.

On the downlink, two channels are introduced to support Node B scheduling: E-DCH Absolute Grant Channel (E-AGCH), which is used to send the base station scheduling information, and E-DCH HARQ Acknowledgement Indicator Channel (E-HICH), which is used to convey transmission acknowledgement messages (such as ACK and NACK) for HARQ processes.

2.2 HARQ Scheme

N-channel stop-and-wait HARQ is adopted in the TD-SCDMA system, and Chase combining and incremental redundancy can be supported.

The HARQ process is as follows: E-DCH channel resources are first allocated by Node B via E-AGCH, and then the ACK/NACK messages are returned via E-HICH. The E-DCH/E-AGCH/E-HICH association and timing is shown in Figure 6.

In Figure 6, n_{E-AGCH} is the interval between the start of the E-AGCH and the start of the first active slot of the subsequent E-DCH transmission. The value of this parameter depends on the processing capacity of the UE, and is currently set to be 6 slots (special time slots, Downlink Pilot Time Slot (DwPTS) and Uplink Pilot Time Slot (UpPTS), are not taken into account). n_{E-HICH} is the interval between the last active slot of the E-DCH TTI and the start of the transmission of the ACK/NACK on E-HICH. This parameter is configured by higher layers within the range of 4 to 15 time slots (special time slots, DwPTS and UpPTS, are not taken into account). The HARQ-related uplink/downlink signaling information carried by E-UCCH includes HARQ process ID (3 bits) and Retransmission Sequence Number, or RSN (2 bits). Other information such as the number of HARQ processes and n_{E-HICH}-related messages are configured by higher layers.

2.3 Node B Scheduling Process

(1) A brief Node B scheduling process in HSUPA goes as follows:

a. The UE makes a scheduling request to Node B via E-RUCCH, which contains the scheduling information and UE ID. The UE ID is the E-DCH Radio Network Temporary Identifier (E-RNTI). The scheduling information includes such messages as the Serving and Neighbor Cell Path Loss (SNPL), UE Power Headroom (UPH), and buffer status.

b. Upon receiving the request, Node B scheduler will respond with an access grant message via E-AGCH if it allows the UE to send uplink enhancement data. In the access grant message, power grant, physical resource grant, E-RNTI and E-HICH Indicator (EI) should be included. As E-AGCH is a shared channel, E-RNTI is used to indicate which UE the access grant is given to. EI is the indicator of E-HICH, and is used to indicate which E-HICH will be used to convey the acknowledgement message.

c. Then the UE will demodulate the access grant message on E-AGCH from Node B and find out if the message is for itself. If it is, the UE will decide a rate to begin data transmission on E-DCH based on allocated resources and power. The UE with access grant can carry scheduling information again at the MAC-e end.

d. Once Node B receives and demodulates the data on E-DCH, it will return ACK or NACK to the E-HICH the UE is monitoring, depending on whether the data is correct or not. Finally, the UE will decide if the retransmission is necessary according to the received ACK or NACK message.

(2) The information carried on E-AGCH includes:

a. Power grant: specifying the maximum power that can be allocated to the UE.

b. Physical resources grant: denoted by means of a code and a timeslot component. For simplification, all the allocated timeslots use the same code.

c. E-RNTI: used to identify the UE the access grant is given to.

d. Resource Duration Indicator (RDI): indicating the effective scheduling time for the purpose of reducing the scheduling grant frequency.

e. EI: indicating the UE that which E-HICH will be used to convey the acknowledgement message.

f. E-UCCH Number Indicator (ENI): indicating the number of E-UCCHs multiplexing with E-PUCH.

g. E-AGCH Cyclic Sequence Number (ECSN): used for outer loop power control of E-AGCH.

(3) The contents of the scheduling information are:

a. SNPL: indicating the path losses of the serving cell and neighbor cells.

b. UPH: indicating the power available to the UE.

c. Total E-DCH Buffer Status (TEBS): indicating the buffer status of the UE.

d. Highest Priority Logical Channel Buffer Status (HLBS): indicating the usage status of the highest logical priority channel buffer, and the percentage of total buffer being used.

e. Highest Priority Logical Channel Identification (HLID): used to identify the highest priority logical channel.

3 Progress of TD-SCDMA HSUPA Standardization

To promote the standardization of

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TD-SCDMA HSUPA, in 3GPP RAN#31 meeting, held in March 2006, Datang, together with other companies, proposed to setup TD-SCDMA HSUPA. The proposal was approved during the meeting.

Later, several 3GPP RAN working groups worked out related technical specifications and started the standard research. Among the working groups, RAN1 and RAN2 have been working on physical layer protocols and MAC layer protocols at the air interface, respectively; they have been studying the modification of the protocols and its effect. As the entity, MAC-e, is added to Node B, which has certain effects on the network structure, and the new feature and performance parameters have to be analyzed, RAN3 and RAN4 were set up to do related researches.

Since the work item was launched, three RAN meetings were held. Up to now, 70% of the work item has been done, including basic physical layer structure, HARQ timing and signaling, Node B scheduling, modulation scheme, random access process, E-RUCCH and E-AGCH structures and coding, uplink signaling, UE capability, overall protocol frame, features of E-DCH, QoS control, mobility management, and Iub interface. However, the studies of some hot issues, such as E-HICH structure, scheduled/non-scheduled transmission multiplexing and whether 20ms TTI is supported or not, are still in progress, and they are expected to be completed in the RAN plenary meeting in 2007. The standardization of TD-SCDMA HSUPA will be documented in R7, which is surely a great promotion to the development of TD-SCDMA.

References

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[2] 3GPP TR25.827 1. R1-063619. 28 Mcps TDD Enhanced Uplink [S]. 2006.

Biography

Hu Jinling got her master's degree from Beijing University of Aeronautics and Astronautics. She is now a senior technical manager at Datang Mobile Communications Equipment Co., Ltd, and has been engaged in the research on mobile communications and radio access. She has obtained certain accomplishments in the study of TD-SCDMA standardization. As one of the chief drafters, she has participated in preparing and submitting the TD-SCDMA standard documents to ITU and 3GPP, and has written TD-SCDMA physical layer specifications and related documents. She is now in charge of the technical research and standardization of TD-SCDMA HSDPA/HSUPA; she is also participating in drafting several industry standards of TD-SCDMA at China Communication Standards Association (CCSA).

Roundup

TELUS and ZTE Launch Award Winning Wireless Phone Featuring Fastap Keypad

August 9, 2007, Vancouver, B.C.— TELUS, a leading national telecommunications company in Canada, and ZTE Corporation ("ZTE"), a leading global provider of telecommunications equipment and network solutions announced today the exclusive availability of the ZTE D90, featuring Digit Wireless' Fastap keypad. The ZTE D90 is the first mobile handset in the world to feature both Zi Corporation's eZiType software for increased data input speed and accuracy, and the Digit Wireless Fastap keyboard, which dramatically simplifies the text input experience. With today's announcement, ZTE became the first wireless phone manufacturer from mainland China to directly offer a device for sale in Canada.

"Canadians are now sending more than 21 million person-to-person text messages each day. The ZTE D90 from TELUS merges the hottest mobile messaging and entertainment services with the award winning design of the Fastap keypad, and Zi Corporation's eZiType engine to deliver a highly functional and stylish device that is easy to use and helps our clients save time," said Stephen Ospalak, TELUS vice president of Subscriber Devices.

Earlier this year, the ZTE D90 was recognized for its innovative design, winning the German design association's (Design Zentrum Nordrhein Westfalen) prestigious Red Dot Product Design Award.

The ZTE D90 incorporates a unique Fastap keypad that combines innovative use of backlighting with semi-transparent key graphics. At first glance, the Fastap keypad looks like a standard 12 button phone creating a sleek appearance. When in use, the Fastap keypad lights up, instantly revealing the letter keys for a true one-touch text entry experience simplifying the use of all messaging and TELUS SPARK services.

Additionally the ZTE D90 features "hot keys", enabling one-click access to many services, applications or contacts right from the idle screen. The user is able to easily personalize "hot keys" to many applications and contacts. For example, pressing and holding M to access Messaging or pressing the first letter of a contact's name is much easier to remember than an obscure speed dial number.

The ZTE D90 is also a multimedia powerhouse which gives clients full access to our most popular SPARK services. These include TELUS Mobile Music full track download service, TELUS Mobile Radio (powered by XM Radio), Windows Live Messenger, TELUS My Email for accessing select POP3 e-mail solutions including Hotmail and Yahoo and location-based services such as TELUS Navigator and TELUS Kid Find to help users locate destinations and family.

The ZTE D90 operates on TELUS' wireless high speed (EVDO) network and features a built-in 1.3 megapixel digital camera with zoom and nightmode, Bluetooth support for compatible accessories such as a stereo headset, expandable MicroSD port, and a stylish black flip phone design with soft-touch exterior. (ZTE)

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