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METHOD OF REAL TIME DATA MULTIPLEXING IN LTE RADIO CHANNEL

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МЕТОД МУЛЬТИПЛЕКСУВАННЯ ДАНИХ РЕАЛЬНОГО ЧАСУ В РАДІОКАНАЛІ LTE

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МЕТОД МУЛЬТИПЛЕКСИРОВАНИЯ ДАННЫХ РЕАЛЬНОГО ВРЕМЕНИ В РАДИОКАНАЛЕ LTE

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Abstract. This paper focuses researches in wireless communication technologies with respect to “machine-to-machine” network applications. The LTE physical and data link layers are considered towards the possible adaptation of the OFDM based resource grid scheduling for enhanced real time data transmission. It is concluded that LTE standard actually allows an ad hoc mode of radio channel utilization with partial separation of virtual channel for particular purposes. This virtual channel enables provision of diverse virtual circuits to transfer multiplexed real time data with 10 times less latency comparatively to regular LTE frame cycling. The implementation of proposed method may require further evolutionary supplements in LTE specifications.

Key words: LTE, resource scheduling, teal time data, multiplexing.

Анотація. Стаття присвячена дослідженню безпроводових телекомунікаційних технологій з точки зору їхнього застосування у мережах типу «машина-з-машиною». Розглянуто фізичний та канальний рівні LTE на предмет адаптації розподілу ресурсної сітки OFDM задля удосконалення передачі даних реального часу. Дійшли висновку, що стандарт LTE принципово дозволяє використання радіоканалу в нештатному режимі з частковим виділенням віртуального каналу для особових цілей. Цей віртуальний канал уможливлює передачу мультиплексованих даних реального часу через окремі віртуальні з`єднання з 10 разовим зменшенням часу затримки порівняно з синхронізацією базового фрейму LTE. Впровадження запропонованого методу може вимагати подальшого еволюційного розширення специфікацій LTE.

Ключові слова: LTE, розподіл ресурсу, дані реального часу, мультиплексування.

Аннотация. Статья посвящена исследованию беспроводных телекоммуникационных технологий с точки зрения их применения в сетях типа «машина-с-машиной». Рассмотрены физический и канальный уровни LTE на предмет адаптации распределения ресурсной сетки OFDM для совершенствования передачи данных реального времени. Сделан вывод о том, что стандарт LTE принципиально допускает использование радиоканала в нештатном режиме с частичным выделением виртуального канала для специальных целей. Этот виртуальный канал обеспечивает передачу мультиплексированных данных реального времени через отдельные виртуальные соединения с 10-кратным уменьшением времени задержки по сравнению с синхронизацией базового фрейма LTE. Внедрение предложенного метода может потребовать дальнейшего эволюционного расширения спецификаций LTE.

Ключевые слова: LTE, распределение ресурса, данные реального времени, мультиплексирование.

The concept of general mobility along with the broadband wireless access is one of the core principles of next generation networks (NGN) architecture. The wireless broadband access platform is based on the two standards of the fourth generation (4G) for mobile communications; these two standards are Long Term Evolution-Advanced (LTE-A) and Wireless MAN-Advanced (IEEE 802.16m which is also referred to as WiMax-2) [1]. LTE-A as a major enhancement of the Long Term Evolution(LTE) standard was submitted to ITU-T in 2009 to meet requirements of IMT-Advanced, and afterwards was standardized by 3rd Generation Partnership Project (3GPP, 2011) in its Release 10 [2]; that year the commercial deployment of LTE networks started. Now, the LTE mobile networks are presented in all of the world continents [3]. In contrast to the previous generation of wireless technologies, the LTE radio channel is completely designed on the packet based platform, yet circuit switched technique is also embedded to certain degree into the media access sub-layer due to the particular channel resource scheduling. Some of deployed LTE networks (like Verizon Wireless, AT&T etc.) have experienced of about 50 millisecond one way delay (OWD) in voice connection across the regional geographic domain [4]. Provision an adequate OWD of about 100–150 milliseconds across the world globe is still a problematic issue for LTE based systems. The LTE technology mainly targets the broadband multimedia communication whereas the QoS guaranteed voice connection is primarily offered service on the Voice over LTE (VoLTE) platform within the Multimedia over Telephony (MMTel) network architecture [5].

However, new challenges emerge last years with respect to machine-to-machine (M2M) fast data exchange in distributed wireless sensor networks. These new realities require more researches in mobile technologies to provide higher dynamics and scalability of channel resource scheduling. *This work aims to present an advanced method of real time data multiplexing in LTE radio channel.*

The LTE downlink resource scheduling. In this section we will analyze some features of LTE access layer which are critical for dynamic object interaction in real time mode. The LTE radio channel drives the orthogonal frequency division multiplexing (OFDM) in two possible manners: frequency division duplex (FDD) and time division duplex (TDD) [6]. Both FDD and TDD provide 10 millisecond frame cycling, though the LTE frame is logical entity formed by two distinct half-frames: downlink half-frame (DLF) and uplink half-frame (ULF). Two half-frames (DLF and ULF) in the FDD framework run parallel and last 10 ms each; in turn, TDD half-frames run sequentially one after the other and last 5 ms each (whereas complete LTE frame has 10 ms duration in any case). The simplified scheme of LTE framing in FDD mode is shown in Fig.1, where eNB stands for evolved node base station (it is the hardware connected to the mobile phone network communicating directly with mobile handsets like a base transceiver station in GSM networks); UE stands for user equipment device (mobile phone set).

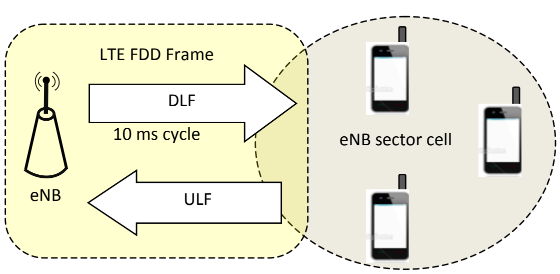


Figure 1 – The general framework of the LTE access network

The LTE downlink half-frame (DLF) is formed on the base of the OFDM time-frequency resource grid (TFG) where elements of TFG are subcarrier symbols (SCS). Each SCS may bear m bits of information respectively to the actualized quadrature amplitude modulation (QAM): $m=2$ for quadrature phase shit keying (QPSK); $m=4$ for 16-positioned quadrature amplitude modulation (16QAM); $m=6$ for 64-positioned quadrature amplitude modulation (64QAM). The set on N SCS forms one OFDM symbol (denote it as one LTE *word*), where N depends on the frequency band used for radio access channel (e.g. $N=180$ for 3 MHz band). The LTE words are grouped in 1 ms sub-frames each containing l words where l depends on the word cyclic prefix (CP) length: if normal CP used then $l = 14$; if extended CP then $l = 12$. The overall DLF structure depends on the set of optional parameters; some typical configurations of these parameters can be defined in online mode along with [7]:

- Duplexing mode (FDD or TDD);
- Serial number of the MBSFN sub-frame (Multicast Broadcase Single Frequency Network) which can vary from 1 to 8 or to be none at all; channel bandwidth (1.4, 3.0, 5.0, 10.0, 15.0, 20.0) MHz;
- Cyclic prefix (normal, extended);
- Total number of wireless physical ports (PNR=1, 2, 4) and transmission ports number: if PNR=1 then Tx=0; if PNR=2 then Tx=(0, 1); if PNR=4 then Tx=(0, 1, 2, 3);
- Physical layer cell ID (PhID) varying from 0-503; this defines three subordinated options:
- ID group=Int(PhID/3); ID=PhID–Int(PhID/3); reference signal (RS) shift=Rest(PhID/6); for instance, if PhID=10, then ID group=3, ID=1, RS shift=4;
- Control format indicator (CFI=1, 2, 3); it defines the number of first LTE words used to carry control information in any sub-frame;
- PHICH Ng factor where PHICH stands for Physical Hybrid automatic repeat request (ARQ) Indicator Channel); Ng=(1/6, 1/2, 1, 3) is a special parameter that determines how many PHICH groups can be supported by a system bandwidth (or related number of resource blocks) according to the Tab.1, [8];
- PHICH duration: normal (one OFDM symbol, i.e. one word) or extended (3 words); this option is correlated to the Control format indicator CFI; if “extended” PHICH duration is chosen then CFI must take value 3; to alternate the CFI parameter the PHICH duration must be turned to “normal” (one OFDM symbol).

The online LTE resource grid simulator [7] has a special interface to point flashing marker on particular DLF resource grid control information: PCFICH (Physical Control Format Indicator Channel), PHICH (spoken above and PDCCH (Physical Downlink Control Channel) in terms of Resource Element Group (REG) embracing six TFG elements within a predetermined sub-frame. Figure 2 illustrates the lower subset of the DLF resource allocation for channel bandwidth =3 MHZ, extended CP, two antennas (with transmitting port number 0), PhID=0, CFI=3, PHICH Ng factor =1, PHICH duration = “extended” (3 words of control information within any sub-frame).

Table 1 – PHICH Ng factor

N_RB \ Ng	1/6	1/2	1	2
6 (1.4 MHz)	1	1	1	2
15 (3 MHz)	1	1	2	4
25 (5 MHz)	1	2	4	7
50 (10 MHz)	2	4	7	13
75 (15 MHz)	2	5	10	19
100 (20 MHz)	3	7	13	25

The full DLF has 15 physical resource blocks (PRBs) whereas first 8 of them are shown in Fig.2. Denote multiplication of 12 subcarrier elements of the OFDM symbol (word) within a PRB by 12 words within a sub-frame as virtual ad hoc segment (or ADS) with respect to its possible utilization beyond the conventional standard specification. In extended CP applied then one ADS equals 12 subcarrier elements ×12 words = 144 elements; if normal CP used then one ADS equals 12 subcarrier elements ×14 words = 168 elements; each element my bear 2, 4 or 6 bits.

The allocation of control information across the DLF is a certain extent symmetric towards the median PRB number 7 which is crossed by conditional “direct current” (DC) subcarrier. Three PRBs below the central PRB7 (from PRB4 to PRB6) look similar to above resource blocks PRB8 – PRB10. All the other PRBs and related ADSs (e.g. PRB0 – PRB3 in Fig.2) have typical structure towards white colored elements (payload user data); in this location one ADS block is shown in the sub-frame 1 × PRB2.

The highlighted ADS segment in Fig.2 has three first colons occupied by control elements of various types; among them: two red-color elements of cell-specific Reference Signal (RS) for selected Tx-antenna port, and two black colored elements for unused by selected Tx-antenna port or undefined for all ports. The last nine colons of ADS have 12 reserved elements (six red-colored RS and six black-colored unused). The rest of (9×12)–12=96 elements are free for user data.

Eventually, we will focus the user data block of 96 elements within a distinct ADS consider the 16QAM modulation type. Thus, the overall payload capacity of such ADS is (4 bits×96 elements)=384 bits or 48 bytes. This payload user data block we denote as virtual ad hoc packet (VAP). According to the LTE physical layer specification, the sequence VAP regular circulates in down link channel with frequency of 1 KHz (i.e. with 1 ms cycling). This property of the DLF scheduling we will exercise in ad hoc mode for enhanced multimedia data transmission over the LTE network.

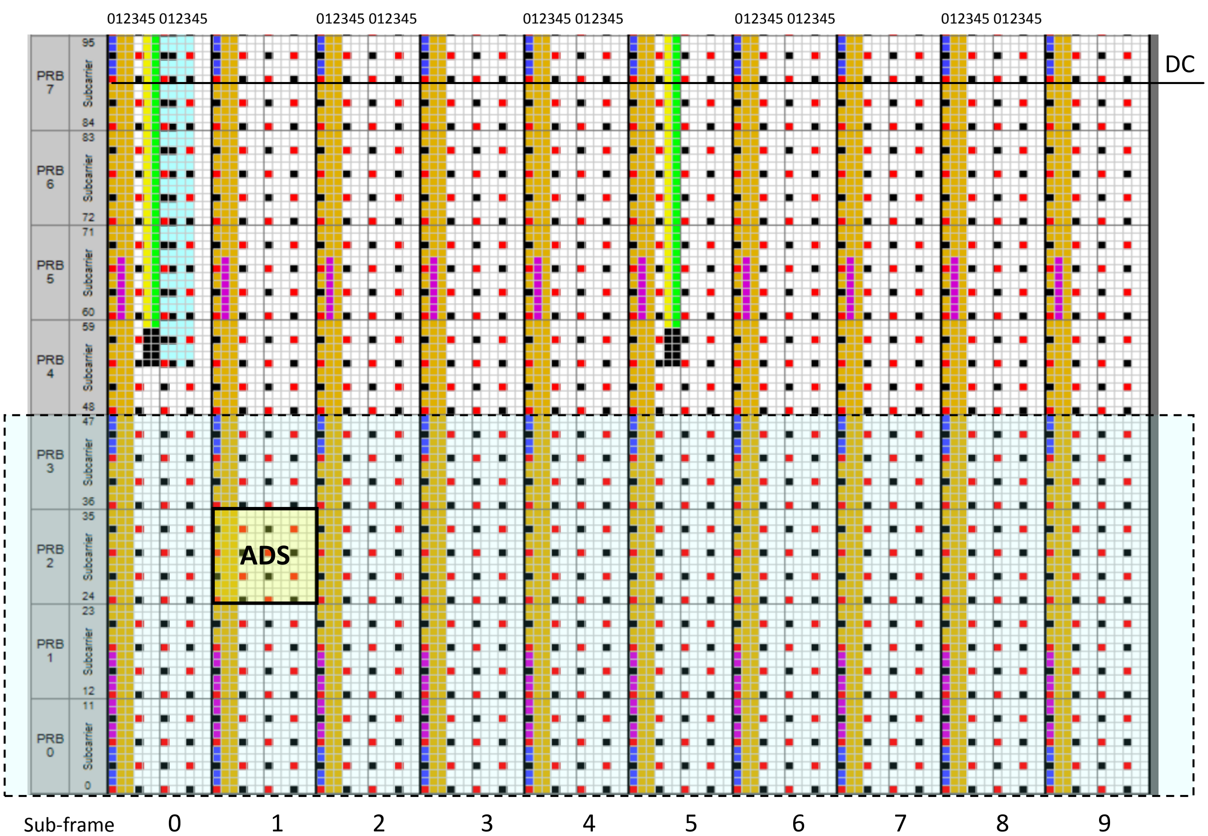
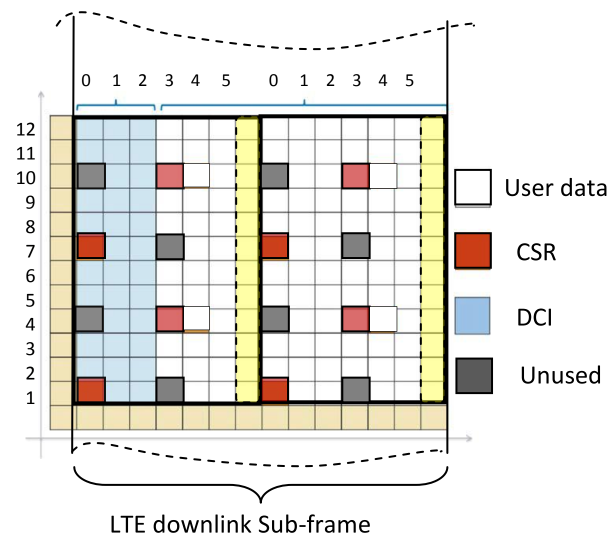


Figure 2 – The DLF resource allocation framework

Real time data multiplexing in LTE radio channel. Consider determined above virtual ad hoc segment (ADS) shown in Fig. 3,a with respect to enhanced real time data transmission over the LTE radio channel. Let the sequence of ADSs in a fixed PRB area (e.g. PRB2 in Fig.2) be redefined for particular utilization beyond the conventional UE service. Each segment within the ADS-sequence we will handle as synchronous transporting module (STM) of physical layer in LTE access network; the user data block (virtual ad hoc packet VAP) we determine as virtual data link layer ad hoc frame in terms of OSI reference model. Thus, we obtain the virtual ad hoc channel (VACH) of (48 byte × 8 bit/byte × 1 KHz) = 384 Kbps capacity. This virtual channel operates with 1ms latency (this is ten times less than standard LTE frame latency); therefore, this virtual channel can be used for particular applications (e.g. wireless communication between electronic devices in sensor networks or M2M domains).

One of the simple ways to benefit the virtual ad hoc channel VACH determined above is simulation the circuit switch mode for data transmission due to the predetermined virtual connections (VCN); these VCN can be either permanent according to some agreements or to be dynamically switched due to specific signaling protocol. Each element of virtual ad hoc packet VAP we have determined as 4 bit entity which is convenient to present as a string in hexadecimal form, Fig. 3,b. The first VAP-element (4 bits) contains the number of protocol to handle the VPA; the second element encodes the typical variants of VCN-segments allocation; the last two elements contain 8-bit cyclic redundancy checksum (CRC) of entire VAP. Each VCN-segment may take the even number of elements (it is multiple of one byte). The partitioning of the VAP payload among the diverse VCNs is arbitrary (due to the established virtual circuits). The minimal size of VCN-segment is 1 byte, the maximum is (96–4)/2=46 bytes. To support the circuit switch mode of ADSs processing, an appropriate switching function must be provided in the eNB entity. In case of dynamic VCN reconfiguration the related signaling protocol has to be mounted in eNB. In this way, the LTE downlink frame is divided in two parts: a) regular partition delivered with 10 ms cycling; b) ad hoc partition in the form of ADS-sequence with 1 ms cycling intended for real time data transfer over the radio channel.

a)



b)

Virtual ad hoc packet VAP

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	…	94	95	96
Protocol	Type	VCN1				VCN2						…							CRC	

Figure 3 – The structure of virtual ad hoc segment (ADS)

Many network based applications such as machine-to-machine distributed systems, sensor networks and others are critically sensitive to the telemetry data latency and control information time delays. Therefore, an actual issue is adaptation of advanced mobile communication platforms like LTE to the increased demands in dynamic object interaction. The paper introduces an enhanced method of real time data multiplexing in LTE radio channel. This method provides an effective time delay reduction from 10 ms to 1 ms for particular dedicated class of network objects which are handled in ad hoc circuit switching mode through arbitrary data segment allocation within the virtual ad hoc packet of 48 bytes length and 46 bytes payload for real time data. Further researches in this direction imply development the methods of latency restriction in packet-based segments of transporting infrastructure for real time data. The implementation of proposed method may require new steps in LTE specification evolutionary progress.

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