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Application of D2D in 5G Networks

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A technical magazine that keeps up with the latest industry trends, communicates leading technologies and solutions, and shares stories of our customer success

ZTE Makes Breakthrough in 5G Research to Bring Next-Generation Networks Closer to Reality

15 April 2015, Shenzhen — ZTE announced a breakthrough in 5G research, with the company's new multi-user shared access (MUSA) technology demonstrating the capability to more than triple overload capacity of wireless access networks.

Based on the simulation results, ZTE's MUSA algorithm delivered an over 200% improvement in the overload radio, helping to transition networks for the era of the Internet of Things. MUSA is one of ZTE's industry-leading research projects on Pre5G, which use 5G-ready technologies to provide commercial 4G LTE end users with 5G-like access experience. Other Pre5G technologies developed by ZTE include massive MIMO, and ultra-dense network (UDN). ZTE expects its Pre5G technologies will be commercially deployed in 2015.

ZTE Wins 'Best Network Technology Provider' Prize at Selular Awards 2015

16 April 2015, Jakarta, Indonesia — ZTE is pleased to win the "Best Network Technology Provider" prize at the Selular Awards in Indonesia.

The award recognizes the industry-leading innovations of ZTE, a provider of mobile network solutions to operators in Indonesia including PT Telkom. Deploying ZTE's superior technologies and solutions, Indonesian operators are building the highest-performance networks to bring the best mobile internet experience to consumers and drive increased productivity for businesses.

"ZTE is a leading company that has successfully created a variety of patented technologies, and this helps to strengthen and enhance ZTE's position as the best network technology provider in Indonesia," said Edi Kurniawan, Managing Editor of Selular magazine.

The annual Selular Awards recognizes outstanding achievements in the telecommunications industry in Indonesia, covering categories including handset vendor operator, network vendor, gadget accessory provider and application developer. The awards are organized by Selular magazine, a leading publication in the country's telecommunications industry.

North Rhine-Westphalia Prime Minister and ZTE discuss technological innovation for the region

21 April 2015, Beijing, China / Düsseldorf, Germany — ZTE is taking part in roundtable talks between the Government of North Rhine-Westphalia (NRW) and Chinese investors in Beijing this week. The roundtable discussions were initiated and hosted by NRW Prime Minister, Hannelore Kraft, who was accompanied by NRW's Minister for Economics, Energy, Industry and Commerce, Garrelt Duin. ZTE's CEO Shi Lirong shared the company's thoughts on how ZTE could contribute its technical expertise to help enable digital development in NRW.

Earlier in the year, the Prime Minister of North Rhine-Westphalia released her agenda for digital change in the region and invited ZTE and other ICT companies in NRW to share their ideas. The Prime Minister previously met with Shi Lirong at CeBit, Hannover in March 2015, to discuss the company's latest eGovernment and Smart City solutions. At the roundtable talks in Beijing, both parties continue to discuss possible digital innovations in NRW.

ZTE First-Quarter Profit Jumps 41.9% as M-ICT Strategy Spurs Growth

23 April 2015, Shenzhen — ZTE reported first-quarter net profit rose 41.9%, as the company's new M-ICT strategy generated new growth avenues.

Net profit attributable to shareholders of the listed company increased to RMB 883 million (US$142 million) in the first three months, according to the results announcement posted by ZTE Today. Basic earnings per share climbed to RMB 0.24, while revenue rose 10.2% to RMB 21 billion.

Operating revenue from telecommunications software systems, services and other products increased by 23.4% in the first quarter, as ZTE recorded strong growth from video and network terminal products, in addition to services. Under the company's M-ICT strategy, ZTE is focusing on new innovative products to capture the growth in demand for solutions in cloud computing, big data, smart city and high-performance routers, helping carriers and enterprise customers capitalize on opportunities in the era of mobile broadband and Internet of Things.

Revenue from carriers' networks increased by 8.9%, as compared to the same period last year, driven by growth in sales of products such as wireless communication systems, wireline switch and access systems, routers and router switches. Operating revenue from handset terminals increased by 7%, as compared to the same period last year, reflecting mainly higher sales of 4G handset terminals.

ZTE Joins the Center for Global Enterprise to Develop Management Insights

22 April 2015, Shenzhen — ZTE announced its collaboration with The Center for Global Enterprise (CGE). With 19 R&D centers worldwide, research is at ZTE's core. Its involvement with CGE allows ZTE to collaborate with leading business and academic organizations toward a common goal of developing management best practices that enable a better globally integrated economy.

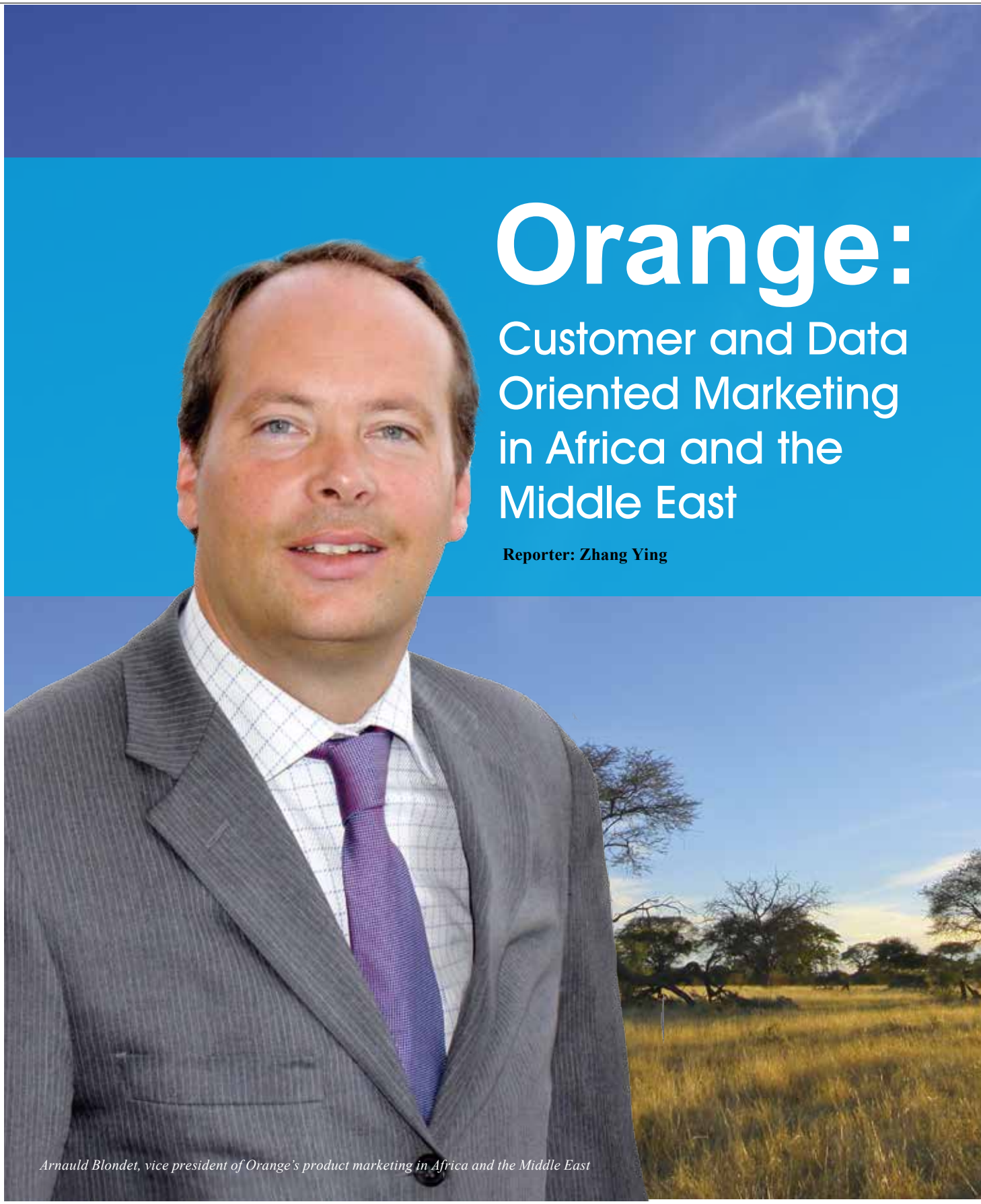
ZTE will be involved in several areas of CGE's research, including the "Business Models for Speed and Scale" and "Emerging Platform Economy" projects. The company will share its expertise in the development of innovative telecommunication and wireless technologies with business and academic leaders to help establish contemporary management practices that provide global enterprises the tools they need to increase the scale and agility of their operations.

CGE not only enables ZTE to share its knowledge with others around the world, but it also serves as a learning resource for ZTE, allowing all leaders to work together to develop technologies, products and solutions necessary to create and manage a global business environment for a better future.

Orange:

Customer and Data Oriented Marketing in Africa and the Middle East

Reporter: Zhang Ying



Arnauld Blondet, vice president of Orange's product marketing in Africa and the Middle East

Orange is committed to making a difference in a highly competitive world. With its innovations, Orange has rapidly developed in the areas of smartphones and data, especially in Africa and the Middle East. *ZTE Technologies* recently interviewed Arnauld Blondet, vice president of Orange's product marketing in Africa and the Middle East. He talked about Orange's growth, challenges, marketing strategies, and relationship with ZTE.

Q: What are your thoughts on Orange's subscriber growth and service development?

A: Orange's subscriber growth is mainly in Africa and the Middle East. Orange has a presence in more than 30 countries, nearly 20 of which are in Africa and the Middle East. This is where we have still room for new customers and equipment. This year, in Africa and the Middle East our smartphones and data really take off. Customers in Africa were still only using mobile for voice, and we saw a real shift in their usage patterns—from voice only to both voice and data.

Q: What characteristics distinguish the AMEA telecom market from that of Europe?

A: The African and Middle East markets include 54 countries, and there are as many markets as countries. It's very, very different from Europe. The African and Middle East markets are segmented; there are high-end and very low-end customers, so we can't say that we have one market or one service or one kind of customer. We service very different markets, and we have a different position in each one. Ninety-five percent of our market is prepaid and very low ARPU—only from three to five dollars. There is also a high churn rate mainly due to the multi-SIM effect and volatility of the market. The African and Middle East markets are still mainly SIM only, and the Europe market is mainly device-subsidized. Africa and the Middle East are prepaid markets, and Europe is a postpaid market. Also, customers in Africa and the Middle East are only starting to use data whereas in Europe, the majority of the population uses data.

Q: What is competition like in Africa and the Middle East and how do you differentiate yourself?

A: We have very strong competitors in Africa and the Middle East, including MTN, Etisalat, Vodafone and Airtel. These are usually multi-country operators with good knowledge of market specificities and needs. I think we all struggle to get the best value share through different positioning. Strategies and execution differ from one country to another and from one operator to another.

Orange's target is really to differentiate customer experience and increase satisfaction. Our specific focus is on innovation. We have Technocentre in which we explore new services and innovations for Africa and the Middle East. We have one Technocentre in Amman, Jordan, and another in Abidjan, Cote d'Ivoire. These centers enable us to have local knowledge and work on new innovations for these markets.

Q: What marketing challenges do you face? How do you overcome them?

A: We have many challenges—from the segmented nature of our value propositions to winning customers with new technology, which means we need to learn how to improve their usage of telecom technology. Our customers are still relatively young (inexperienced)

An interview

in terms of telecom usage. They learn very early to make calls and use SMS; that is quite easy, but they are still not used to using mobile data and other services. So our marketing challenge is to help them learn how to use their phones more. The technology we present needs to look very easy to them. We are still improving the way we launch new services, and we need to continually learn about our customers and their demands.

Q: How does Orange improve user experience? Can you expand on some of your recent activities for improving experience?

A: Customer experience comes first at all the key touchpoints of the lives of our customers. We need to focus on it by creating value for customers throughout their life. We have three orientations. The first orientation is to innovate and always propose new services. We will launch an abundance of new services that stimulate usage. Then we target personalization and help the user find the right service at the right time. Of course, cost is also still very important in Africa and the Middle East. We view the customer as the head of all our processes—they are right there in the center, not at the periphery. In a word, we listen a lot to our customers, to understand their needs, and for this we need to define tools for better knowing and managing our customers.

Q: Could you please elaborate on your product strategy in the next three years?

A: It's very ambitious. We look at our strategy in four key domains. The first is an open ecosystem and open innovation. We are opening our APIs

> *ZTE is of course a great partner in many areas for Orange. We are one hundred percent satisfied with ZTE. We are working with ZTE in two main areas of innovation: intelligent network and service delivery platform.*

for development of new services. The second is customer experience. We will improve customer experience during their lifetime. The third is core telecom business, which is about QoS, network-based solutions, and core services data. The last is new growth and expanding our territory. We look for new opportunities for growth. One good example in Africa is mobile money. We are very active with Orange money and have launched this in 14 countries.

Q: Could you give examples of your innovative apps or services? What are your market plans this year?

A: We launch many new services each year and learn from all the markets, from all over the world, and define the right services for the upcoming roadmap. An example of what we've launched already is a range of Android apps in Africa and the Middle East. First is Libon, which is a VoIP app for voice and chat, like WeChat. Then we launched an app based on football because Africans are very fond of football, and Orange is a main sponsor of the African Cup of Nations. We have an app called Orange Football Club where we share football information and knowledge with football fans. Then we have an app for customer care called My Orange. This kind of app is launched in all of our branches now. And last, in the area of cloud services, we launched Orange Consumer Cloud, which is a cloud-based app for saving, sharing and storing content.

Q: What is your main goal in Africa and the Middle East over the next few years and how will you achieve it?

A: I would say that the first goal is always customer satisfaction—anticipating and meeting their needs to make them happy. We will do it through new usage and services. We really want to create value for our customers.

Q: Could you share some details about your partnership with ZTE? What are your expectations for ZTE in future?

A: ZTE is of course a great partner in many areas for Orange. We are one hundred percent satisfied with ZTE. We are working with ZTE in two main areas of innovation: intelligent network and service delivery platform. Thanks to ZTE's innovative technology and people, we think ZTE will continue to deliver robust services and innovation in the future.

Q: What do you foresee for Orange by 2020?

A: We need to anticipate where we want to be by 2020. The market for Africa and the Middle East at that stage will be much more data-oriented. And we hope that customers will be much less volatile and we will have much less churn. We will have real intimacy between us and our customers. So our focus from today until 2020 will be customer satisfaction and experience, providing new services and increasing usage. ZTE TECHNOLOGIES

TD-LTE Creates a New-Look 2K Telecom

Reporter: Huang Xinming

2K Telecom is a leading telecom services provider in Romania. The company offers WiMAX connectivity in partnership with a number of companies. 2K Telecom recently cooperated with ZTE on a TD-LTE project financed by the China Development Bank. At Mobile World Congress 2015, 2K Telecom and CDB signed a facility agreement. *ZTE Technologies* interviewed Alexandru Ghita, CEO of 2K Telecom, who talked about 2K Telecom's LTE rollout, development plans, telecom trends, and partnership with ZTE.

Alexandru Ghita, CEO of 2K Telecom

Q: How do you characterize the Romanian telecom market and what is your position in it?

After testing three or four vendors, we found that ZTE had very good technologies and very good relationships with logistics companies and our partners. ZTE proved to be one of the best vendors on the market.

A: The Romanian telecom market is very competitive. In Romania, large multinationals have owned all types of mobile technologies, from 2G to present. We are a local fast-growing company that provides instant time-to-market 4G mobile services at a good price. We have individual, corporate and government customers. We cover well all business segments and requirements in the Romanian market and are an important player in this landscape.

Q: What challenges do you face?

A: The Romanian telecom market is recovering after recent economic crises, and consumers are still a little cautious because of the sluggish economy. Other challenges, especially for mid-sized operators, are volatility of financial markets and funding conditions.

Q: How do you compete against larger established telecom operators?

A: 4G mobile is a major growth opportunity. The market itself is putting pressure on the mobile ecosystem to deliver new services such as M2M, mobile cloud, mobile TV, and NFC. We can control our costs better than our rivals because we don't have the entire suite of technologies dragging us down. Our deployments are mostly greenfield, using technologies that are compact and energy-efficient. Our core network is flat, cheap to maintain, and easy to operate. We signed local roaming and MVNO agreements with operators in order to provide nationwide coverage and mobility for our customers. We benefit from our equipment, based on the latest cutting-edge technology and also used by China Mobile, and we can rapidly deliver a wide array of services.

Q: Your network evolved from WiMAX. What were the biggest challenges during this transition? How did you manage them?

A: WiMAX and TD-LTE share most of the RAN and transmission network, so the transition to TD-LTE was relatively smooth but not totally painless. For instance, in some areas, we decided to deploy TD-LTE as a second overlay network where WiMAX was available in order to guarantee a smooth transition for subscribers. One of the biggest challenges was that earlier WiMAX base stations could only be partly upgraded to TD-LTE, so we need extra support from the vendor. Another problem was that current WiMAX devices do not support TD-LTE and need to be replaced in the future. Reasonably priced multimode devices will make the transition from WiMAX to TD-LTE more attractive.

Q: How is your LTE rollout progressing? How important is TD-LTE in increasing your competitiveness?

A: At the moment, we have built the sites and civil engineering work is underway. We are still waiting for some

An interview

equipment to arrive and have begun testing some of the sites. The technology is working very well, and we have witnessed some very high speeds. In the near future, we will also try to implement carrier aggregation, and we are also looking forward to implementing VoLTE as well.

Q: Why did you choose ZTE to help build your TD-LTE network?

A: Actually, our cooperation started many years ago, I think five or six years ago. At the time, we knew something about ZTE, but we also tested other vendors. After testing three or four vendors, we found that ZTE had very good technologies and very good relationships with logistics companies and our partners. ZTE proved to be one of the best vendors on the market.

Q: How will future cooperation with ZTE progress?

A: We expect ZTE to maintain the high standard of its equipment, which we know and have experience with. In the future, infrastructure will be important, but we also want ZTE to help us with our professional services, connecting the networks, and also devising and implementing new business models.

Q: What is your LTE pricing strategy?

A: At the moment, we are trying to position our services in the market, which is very competitive. There are three big operators; actually, we are the fourth operator with a 4G license. So at the moment, our strategy is to find a good niche where we can sell our services and not go head-to-head with the big operators already ruling the market.

Q: What are your thoughts on fixed-mobile convergence? Do you have any plans for that?

A: It's obvious that this convergence will happen sooner or later. For example, now in our network, some of our sites are already capable of around 200 Mbps and need very good backhaul, which is possible only with fixed technologies. Also, on the consumer side, we are seeing all kinds of fixed services packaged with mobile services, and it's clear that the market is going in that direction.

Q: What are your predictions for the global telecom market?

A: I see Internet of Things being the new development strategy for operators, and also we're starting to look at NFV, which can help many operators decrease their capex and monthly opex. ZTE TECHNOLOGIES

Using SDN for Better IP RAN O&M

Reporter: Yue Lihua

Xu Ming, vice president of ZTE Corporation

Software-defined networking (SDN) addresses many issues in traditional network architecture by decoupling network control and forwarding. SDN has shaken up the networking business, with most vendors either announcing or releasing SDN-related products. ZTE launched its IP RAN SDN system at MWC 2015.

This was the first time ZTE's IP RAN SDN solution had been demonstrated and publicized. *ZTE Technologies* interviewed Xu Ming, vice president of ZTE Corporation, who talked about using SDN to better operate and manage IP RAN in the face of increasing mobile broadband workloads.

Q: How does ZTE see the development of SDN?

A: We think SDN is developing in three steps, and in each one,

ZTE is focused on digging up value for the customer. In the first step, the commercial value lies in using SDN architecture and technology to improve network service. SDN can be introduced to solve issues with existing network technologies. The network can be reconstructed to meet more service needs. SDN also simplifies network O&M. In the second step, SDN architecture and technology is used for service fulfillment. SDN can tightly couple services with networks, further open network capabilities, and speed up service innovation and deployment. In the third step, SDN architecture and technology can be used to increase network value and build an SDN ecosystem.

Q: What progress has ZTE made in SDN?

A: ZTE has built up three basic platforms: an open application-development platform, a controller platform, and an integrated hardware platform. These are the foundation of our development. ZTE's SDN-based bearer network is evolving towards application in the mobile backhaul, service control layer, optical transport layer, and IDC.

Q: What commercial SDN solutions has ZTE launched?

A: In the first step, ZTE has launched commercial solutions for improving network service capability. These solutions include v-IP RAN, SPTN, SDN-based optical network, SDN-based BNG, and SDN-based data center. v-IP RAN aims to simplify O&M and improve network service capability. SPTN helps operators with cross-domain service provisioning. SDN controllers are used for fast, easy, end-to-end service provisioning. An SDN-based optical network can improve operational efficiency. SDN controllers are used for centralized connection control and optimized traffic flow. Changes are made to the existing network in the early stage. This greatly increases network efficiency and helps an operator obtain higher ROI. An SDN-based BNG with NFV applications reduces investment in equipment at the service-control layer. The separation of service control from equipment greatly lowers capex and the requirements on equipment. An SDN-based data center solution comprises data center interconnection (DCI) and internal data center network. The DCI optimally schedules traffic between data centers via SDN controllers, and the internal data center network uses SDN controllers to control bearer equipment and virtual servers. This enables traffic within the data center to be balanced, service capabilities to be developed, and ROI to be increased.

ZTE will focus on SDN robustness, synergy, and reasonable ecological construction.

Q: What benefits can ZTE's IP RAN SDN solution bring to customers?

A: LTE networks are being widely commercialized, and massive base stations have been deployed. This means the number of devices at the access layer of a mobile backhaul network has increased dramatically. Also, as L3 nodes are moved downward to the access layer, network management has become more difficult. There are unprecedented challenges related to bearer networks. ZTE's IP RAN SDN solution introduces SDN architecture and virtualization technology. SDN controllers unify the management of devices at both the access and aggregation layers. A huge number of devices at the remote access layer are virtualized into the boards of aggregation equipment for better management. This significantly reduces the number of IP RAN network elements and simplifies network structure and O&M. We have also developed O&M apps with graphic user interfaces and released PC, PAD and mobile phone versions. Easy one-key operation has completely changed O&M.

Q: How does ZTE market its SDN solutions?

A: ZTE is being proactive in commercializing its SDN-based bearer networks. We have had in-depth exchanges on SDN and commercially trialed SDN for operators around the world. In China, we have established a strategic SDN partnership with China Unicom and have trialed commercial v-IP RAN for Jiangsu Telecom and Zhejiang Telecom. We have run six SDON commercial trials in Africa, South America and Southeast Asia; two vBAS commercial trials in Southeast Asia; and several IDC trials in Africa, America, Europe and Southeast Asia. We have also signed strategic cooperation agreements with MTOs.

Q: What's your next focus with the SDN solution?

A: Next, ZTE will focus on network robustness, synergy, and reasonable ecological construction. SDN robustness implies reliability and security in the SDN architecture. Security is required between the application layer and control layer and includes application authorization, authentication, isolation, and strategic conflict resolution. Security can be guaranteed between the control and infrastructure layers by refining OpenFlow specifications. Implementing traditional network applications, such as access control, firewall, intrusion detection and intrusion defense on relative APIs of SDN controllers, is worthy of more study. Moreover, creating new network security applications based on SDN architecture will be a future trend. Greater attention needs to be paid to the reliability of large-scale SDN architecture, especially the robustness of SDN controllers and their fast protection. The normal distribution of control flow for special cases, such as congested traffic, also needs to be researched. Synergy capability in SDN architecture is also an important issue that needs to be studied at a later stage. In the early stage, we talk about optimization and solutions related to each layer of the network. The main concern is to integrate these network optimization and solutions into one core controller and break the original bandwidth management layers for bandwidth resource integration, virtualization, and flexibility.

We have built three basic platforms: an open application-development platform, a controller platform, and an integrated hardware platform. Using the app development platform, we have developed a series of apps in different scenarios for improving network service capability. In the future, we will provide an open app development platform for a third party. On the open platform, developers can develop their own apps to enrich the upper-layer applications. We will also offer a universal hardware platform to third parties and joint together with all partners in the industry to build a new vibrant SDN ecosystem. ZTE TECHNOLOGIES

Progress on 5G Radio Link Enhancement

By Xu Jun

Xu Jun, senior expert and program director for radio link enhancement at ZTE Corporation

Future 5G networks will be primarily designed to improve system performance and support new services. 5G networks will:

- increase capacity a thousand-fold
- increase single-user data rates ten-fold to a hundred-fold
- reduce service delay by one fifth
- increase the number of terminal connections a thousand-fold
- support new services, such as device-to-device (D2D), machine-type communication (MTC), vehicle-to-X (V2X), and ultra-reliable communication (URC).

Most of the key requirements of 5G are closely related to radio links. Enhancing radio link techniques is critical for 5G evolution.

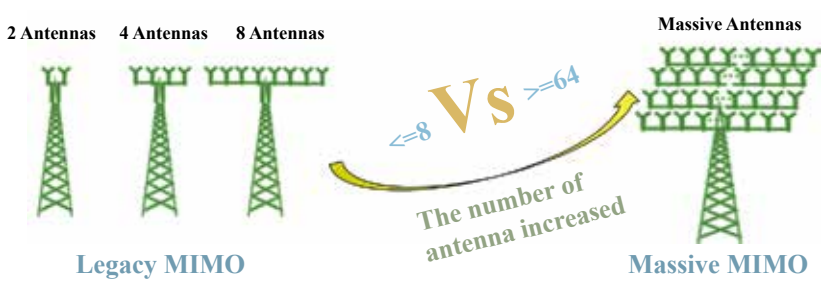


Figure 1. Legacy MIMO and massive MIMO.

Potential Techniques for Enhancing the 5G Radio Link

New radio link techniques involve massive MIMO, new multiple access, new coding modulation, enhanced HARQ, network coding, advanced receivers, and virtual MIMO.

Massive MIMO

Massive MIMO allows tens to thousands of arrays to be configured at the base station. This enables more precise beam control and higher spectral efficiency than legacy MIMO, where there are fewer than eight antenna arrays (Fig. 1). Massive MIMO also involves the use of spatial multiplexing and interference mitigation to increase system capacity; however, related channel information acquisition, antenna array design, codebook design, and reference signal design still need further research. Coordinated multi-point transmission

(CoMP) is distributed massive MIMO, and centralized massive MIMO is an extension of CoMP.

New Multiple Access

In non-orthogonal multiple access (NOMA), information at the transmitter side is superposed in the power domain or code domain and is demodulated at the receiver side using SIC or ML demodulation. NOMA can be used in near-far scenarios to ensure maximum fairness between users and obtain the maximum sum rate. Currently, NOMA can be classified as power-domain or code-domain. To a certain extent, power-domain NOMA is an extension of the spatial, time or frequency domains and enables more users to access the system when resources for these domains are limited. Code-domain NOMA includes low-density CDMA and interleave division multiple access (IDMA). NOMA is mainly used in scenarios where there are too many users, or access cannot be easily synchronized. It can also be used when a base station has a relatively small number of antennas. Such a scenario arises in ultra-dense networks, large-scale and high-density user areas, D2D communication, M2M communication, and sensor networks.

Filter-bank multi-carrier (FBMC) is a frequency-division multiplexing technology that uses a group of filters to divide channel spectrum for frequency reuse. An FBMC system comprises synthetic filters at the transmitter side and analytic filters at the receiver side. FBMC outperforms OFDM in reducing out-of-band leakage and is particularly suitable for dynamic spectrum sharing. FBMC/OQAM increases system efficiency without cyclic prefix (CP) guard. FBMC does not require synchronization for uplink access channels.

New Coding Modulation

For high reliability, high throughput and low latency, much attention must be paid to technologies with multiple domain coding, grid coding modulation, low-bitrate short-to-medium length codes, new link-adaptive coding modulation based on error bitrate or error block rate estimation, gigabit ultrafast decoder, and physical-layer packet coding.

Enhanced Hybrid Automatic Repeat Request (HARQ)

To meet high-throughput and low-latency requirements, a 5G system needs to reduce HARQ retransmission, MAC-layer latency, and feedback overhead and increase retransmission. Enhanced feedback-based HARQ or packet-coding techniques can be used to reduce latency and HARQ retransmission; a new code bit selection and retransmission mechanism can be used to improve retransmission performance; and new feedback channel design schemes and iterative receivers can be used to reduce feedback overhead.

Network Coding

The basic concept of network coding is that network nodes are allowed to combine and retransmit information they have received. Relay nodes combine and encode information from different links. Network nodes function as both routers and coders. With a legacy data transmission policy, the source generates data; intermediate nodes copy, store and transmit the data; and the receiving node receives the data. The data is independent and irrelevant. However, network coding has overturned the idea that independent bits cannot be compressed. Now network information flows can be compressed to further improve spectral efficiency and network throughput.

Advanced Receivers

The computing power of mobile terminals will continue to grow rapidly in the next few decades, as dictated by Moore's Law.

Enhancing radio link techniques is critical for 5G evolution.

IC receivers, iterative receivers, and maximum likelihood (ML) or maximum-a-posteriori (MAP) receivers can be used in a 5G system. Moreover, more advanced receivers, such as receivers with jointly optimized channel estimation, signal detection and decoding, can be applied in the 5G system. Receivers for special scenarios can also be used. Such receivers might be MMC receivers based on the compressed sensing mechanism or receivers for high mobility. In short, advanced receivers can improve spectral efficiency and system throughput.

Virtual MIMO

Because D2D communication is widely used in a 5G system, downlink virtual MIMO enbables multiple local users to share their receiving antennas and form a virtual single user MIMO (SU-MIMO) receiver or virtual diversity receiver (Fig. 2). This can greatly increase link capacity and reliability between the macrocell and terminals. A virtual SU-MIMO receiver improves performance compared to a legacy MU-MIMO receiver; therefore, communication in densely populated hotspots can be significantly improved. A virtual receive diversity receiver enables multiple users at the edge of the same cell to share their receiving antennas. This improves radio coverage at the cell edge, so virtual MIMO improves spectral efficiency and cell edge reliability.

ZTE's Research on 5G Radio Link Enhancement

ZTE's research on 5G radio link enhancement encompasses:

- massive MIMO. ZTE focuses on the design of high-dimensional codebook, reference signals and antenna arrays, and the relationship between massive MIMO and CoMP. ZTE has proposed two codebook models that address the issues of low precision and high overhead in legacy codebooks and has also proposed a compressed sensing-based reference signal design scheme to reduce pilot overhead. ZTE has also set up both link-level and system-level emulation platforms for all these technology domains and has completed several related research papers and patents.
- new coding modulation. ZTE has proposed soft decoding information-based error estimation for rapid link adaptation that can solve the problems of imprecise channel state information (CSI) feedback and a long outer loop link adaptation (OLLA) cycle. ZTE has also proposed multi-domain LDPC coding and new coding modulation schemes that boast lower complexity and better performance than other competing schemes in the industry. ZTE's LDPC coding scheme can properly handle the wait time for inter-layer pipelining in existing hierarchical LDPC decoding. This doubles efficiency or speed without increasing hardware complexity. ZTE has devised a coding block-based packet coding scheme for enhanced system performance and rapid pipelining. Link-level emulation platforms have been set up for the above technology domains as well as for grid coding modulation (Lattice code) and short codes. A hardware platform has also been set up for ultrafast decoders. ZTE has completed several research papers and patents related to this area.
- enhanced HARQ. ZTE has proposed soft ACK/NACK-based and packet coding-based retransmission schemes to reduce HARQ retransmission and latency. ZTE has also defined a new redundant version to improve adaptive HARQ retransmission performance. Both link-level and system-level emulation platforms have been set up for all these technology domains, and even

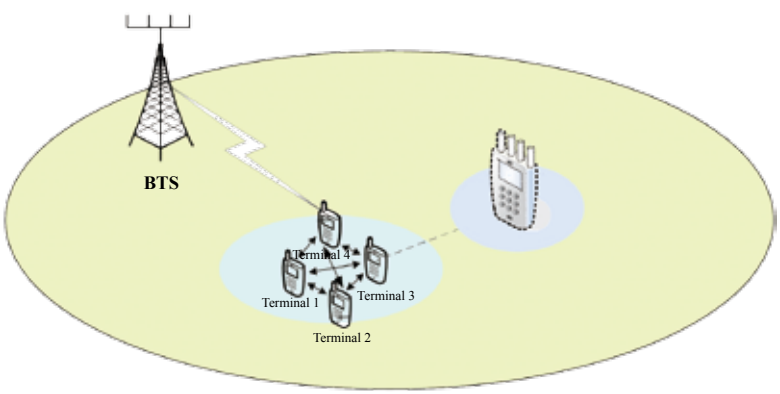


Figure 2. Virtual MIMO for mobile terminals.

prototype verification platforms have been set up for other specific domains. ZTE has completed several related research papers and patents.

- network coding. ZTE's focus of research includes network coding applications in uplink relay transmission, in a homogeneous network, in D2D communication, and in small cell scenarios. ZTE has set up link-level and system-level emulation platforms for all these technology domains and even prototype verification platforms for other specific domains. ZTE has accumulated the relative IPR.
- advanced receivers. ZTE has conducted research into the IRC receiver, SIC receiver, ML receiver, uplink MIMO multiaccess iterative receiver, single-antenna interference cancellation receiver, and jointly optimized receiver. Link-level emulation platforms have been set up for all these technology domains, and system-level emulation platforms have been set for the IRC receiver, SIC receiver, and ML receiver domain. ZTE has also completed several research papers and patents.
- new multiple access. ZTE has studied and evaluated NOMA in the power domain, low-density CDMA, and FBMC. ZTE has also proposed multi-user shared access (MUSA), which is developed based on code division to greatly increase the number of users that can simultaneously gain access. The newly designed code sequence has improved network capacity and prolonged terminal battery life. ZTE has set up link-level or system-level emulation platforms for all these technology domains, and has completed several related research papers and patents.
- virtual MIMO. ZTE has evaluated virtual MIMO technology through the system simulation research. The simulation result shows that virtual MIMO on the terminal side can significantly improve the link capacity between macro cells and terminals. ZTE has also proposed a new concept of coordinated relay cloud and suggested using virtual MIMO to increase backhaul link capacity between macro cells and the relay cloud. ZTE has completed several related research papers and patents.

New requirements will emerge for future 5G. Research on 5G radio link enhancement will start with major 5G scenarios and requirements, and different radio link enhancement technologies will be chosen according to these scenarios and requirements. ZTE has studied in depth all aspects of 5G link enhancement and has made great progress in certain areas. 5G will be a far-reaching system that will certainly change the pattern of the industry and the way we live. ZTE is collaborating closely with the industry and universities to further contribute to 5G development. ZTE TECHNOLOGIES

Application of D2D in 5G Networks

By Wu Shuanshuan

Cellular communication systems have evolved from 1G analog, represented by voice services, to 4G wireless broadband, represented by mobile data, computing, and multimedia. With the prevalence of smart terminals and explosive growth of network traffic, there is a clearer, more pressing need for evolution to 5G mobile technology.

In the evolution to 5G, traditional performance indicators, such as network capacity and spectral efficiency, need to be continually improved, and a wider variety of communication modes and applications need to be provided to enhance user experience. Device-to-device (D2D) technology has drawn widespread attention in the industry for its potential to improve system performance, enhance user experience, and expand cellular applications.

What is D2D?

With cellular-based D2D communication, also called proximity service (ProSe), user data can be directly transmitted between terminals without routing via eNodeBs and core network. D2D communication has a structure quite different from that of a traditional cellular network (Fig. 1).

D2D communication helps increase spectral efficiency, enhance user experience, and expand communication applications.

Increasing Spectral Efficiency

In D2D communications, user data is directly transmitted between terminals without routing through a cellular network and thus results in hop gain. Moreover, resources between D2D users and between D2D networks and cellular networks can be reused, and this results in resource reuse gain. With the hop gain and resource reuse gain, wireless spectral efficiency and network throughput can be increased.

Enhancing User Experience

As mobile services and technologies develop, short-distance data sharing between nearby users, small-scale social and commercial activities, and location-based services for local users will become a significant source of business growth on the wireless platform. D2D technology based on nearby user discovery will enhance user experience in these service modes.

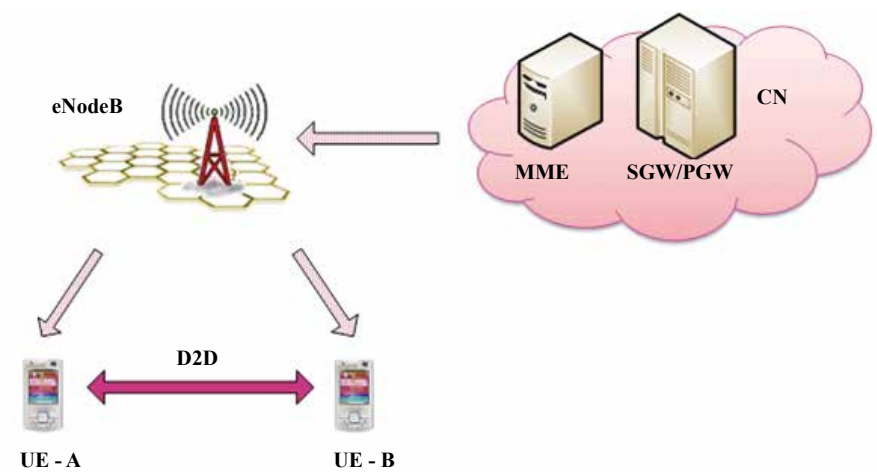


Figure 1. D2D communication structure.

Expanding Communication Applications

Traditional wireless networks were demanding on communication infrastructure. The communication system may collapse if core network facilities or access network devices are damaged. However, D2D communication makes it possible for cellular communication terminals to set up ad hoc networks. If the wireless infrastructure is damaged or terminals are not covered by a wireless network, multi-hop D2D can be used for peer-to-peer communication or even access to cellular networks. In this way, the number of wireless applications can be expanded.

Standardization of D2D in the 3GPP LTE system started with LTE Release 12. Unfortunately, D2D discussed in LTE Release 12 only supports broadcast communication and has very limited functions. The potential gains and applications of D2D need to be developed in future 5G networks.

Potential 5G D2D Applications

Applications of 5G D2D include local service, emergency communication, and IoT enhancement.

Local Service

In local service, user data is directly transmitted between terminals and does not route through the network side.

Local service is typically used for social apps. Social apps based on the proximity feature are a basic D2D application. With the D2D discovery and communication functions, a user can find other nearby users and share data or play games with them.

Another basic application of local service is local data transmission. Local data transmission leverages the proximity and direct data transmission

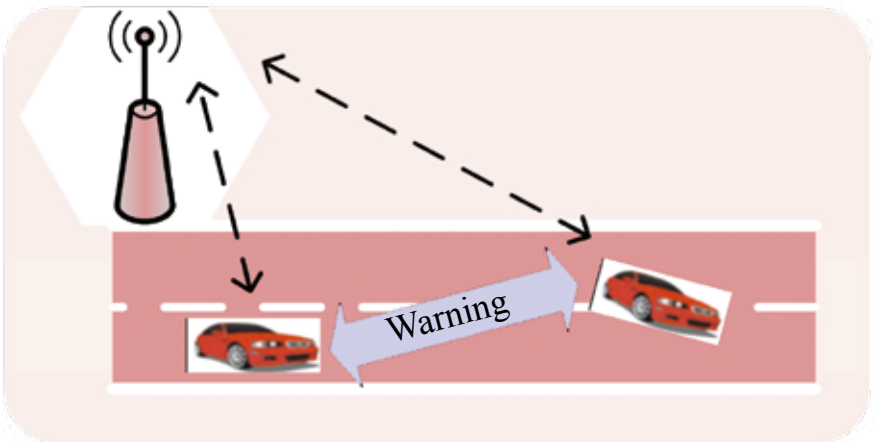


Figure 2. D2D-based IoV application.

features of D2D to expand mobile applications while saving spectrum resources. This creates a new source of revenue for operators. For instance, local advertising service based on proximity can accurately target people to maximize its benefits. A shopping mall can send commercials, discounts and promotions to people who walk into or around the mall, and a cinema can push movie information and showtimes to people nearby.

A third application of local service is cellular traffic offloading. As media services such as HD videos become popular, their massive traffic flows put tremendous pressure on core networks and spectrum resources. D2D-based local media services can help operators save their core network and spectrum resources. In hotspot areas, operators or content providers can deploy media servers that store popular media services. These media servers deliver media services in D2D mode to users. Alternatively, users can use D2D to get the media content from nearby user terminals that have obtained media services. In this way, the downlink transmission pressure of operator cellular networks can be eased. Moreover, the cellular communication between short-distance users can be switched to the D2D mode to offload cellular traffic.

Emergency Communication

When natural disasters such as earthquakes occur, traditional communication network infrastructure can get damaged and the network may even collapse. This greatly hampers rescue efforts. This problem can be solved by introducing D2D communication. Although the communication network infrastructure may be damaged, a wireless network can still be set up between terminals based on the D2D connection. This means that an ad hoc network can be established based on multi-hop D2D to ensure smooth wireless communication between terminals. A wireless network affected by terrain or buildings may have blind spots. With single-hop or multi-hop D2D communication, users in the blind spots can be connected to user terminals that are in coverage areas and then be connected to the wireless network.

IoT Enhancement

One of the goals of developing mobile communication is to establish an extensive interconnected network that contains various types of terminals. This is also one of the starting points for developing the Internet of Things (IoT) in the cellular communication framework. The industry forecasts that by 2020 there will be 50 billion cellular access terminals on a global scale and most of them will be machine terminals with the IoT feature. If D2D is combined with IoT, a truly interconnected wireless network will be created.

A typical application of D2D-based IoT enhancement is vehicle-to-vehicle (V2V) communication in the Internet of Vehicles (IoV). When running at high speeds, a vehicle can warn nearby vehicles in D2D mode before it changes lanes or slows down (Fig. 2). According to the received warnings, nearby vehicles alert drivers or even automatically control the driving in an emergency situation so that drivers can react more quickly to reduce the number of traffic accidents. Furthermore, using D2D discovery technology, vehicles

can reliably detect and identify specific vehicles nearby, such as those vehicles that may cause danger at intersections and those specific vehicles (school buses or vehicles carrying dangerous goods) that need special attention.

Based on the communication delay and neighbor discovery features, D2D communication has inherent advantages when being applied for IoV security.

Because there are many IoT terminals in a 5G network, access load has become a serious issue. However, D2D-based network access is expected to solve this problem. In a scenario where there are many terminals, low-cost terminals can access nearby special terminals in D2D mode instead of being directly connected to base stations. Through these special terminals, connections to the cellular network are established. If multiple special terminals are isolated in space, the wireless resources for access to low-cost terminals can be reused by these special terminals. This not only relieves access pressure on base stations but also improves spectrum efficiency. Furthermore, compared with small cell structure in the existing 4G networks, the D2D-based access mode is more flexible and costs less.

In a smart home application, a smart terminal can be used as a special terminal. Wireless appliances in the smart home access the smart terminal in D2D mode, and the smart terminal can access the base station in a traditional cellular mode. The cellular-based D2D communication may make a real breakthrough for the development of the smart home industry.

Other Applications

5G D2D can also be applied in other potential scenarios, such as multiuser MIMO enhancement, cooperative relaying, and virtual MIMO. In the traditional multiuser MIMO, base stations determine pre-coding weights based on respective channel feedback of terminals to create nulls and eliminate interference between users. After D2D is introduced, paired users can directly exchange information about channel status. In this way, terminals can feed the joint channel status information to base stations and improve the performance of multi-user MIMO.

D2D can also help to solve problems in new wireless communication scenarios. In the indoor positioning, terminals cannot obtain satellite signals when they are indoors. In this case the traditional satellite-based positioning does not work. However, in the D2D-based indoor positioning, pre-deployed terminals with given location information or common outdoor terminals with given position can determine the location of terminals to be positioned, and support indoor positioning in 5G networks at a low cost.

Key 5G D2D Techniques

In the above applications, potential 5G D2D techniques at the access side include:

- D2D discovery. This involves detecting and identifying nearby D2D terminals. For multi-hop D2D networks, this technique should be considered in combination with routing and to meet the needs of special 5G scenarios such as efficient discovery in ultra-dense networks and ultra-low latency in IoV scenarios.
- D2D synchronization. Certain scenarios such as outdoor coverage or multi-hop D2D networks may present a big challenge to system synchronization.
- wireless resource management. 5G D2D communication may include broadcast, multicast, and unicast, and can be used in multi-hop and relay scenarios. Therefore, radio resource management and scheduling in 5G networks is more different and complex than in traditional cellular networks.
- power control and interference coordination. Cellular-based D2D has the advantage of controllable interference over traditional peer-to-peer (P2P). However, cellular-based D2D creates extra interference in cellular communication. Moreover, considering multi-hop and unauthorized LTE-U spectrum as well as high-frequency communication in 5G D2D, research into power control and interference coordination will be critical.
- communication mode switching. It includes the switching between D2D and cellular modes, between cellular D2D and other P2P (such as WLAN) modes, and between authorized spectrum D2D and LTE-U D2D modes. Advanced communication mode switching can maximize the performance of wireless communication systems.

As the number of terminals continues to increase in a super-linear way and there are more diverse needs for services, D2D will play an important role in the 5G era to support the wireless development vision of building a truly extensive interconnected mobile network. ZTE TECHNOLOGIES

Outlook for IoT Communications in the 5G Era

By Xie Baoguo, Dai Qian, and Xia Shuqiang

In the 5G era, with the popularity of e-banking, e-learning, e-health, the development of network society will create a surge in mobile and wireless traffic. It is estimated that by 2020, data traffic will grow 1000 times compared to 2010.

In the 4G era, five billion items are connected worldwide. In the 5G era, 100 billion massive wireless connections involving the vast majority of consumer products, industrial products and logistics will be established. What's more, 5G Internet of Things (IoT) cloud will integrate cloud computing and big data technologies to build an intelligent society.

The main applications of IoT include intelligent industry, intelligent agriculture, intelligent transportation, smart grid, smart home, smart city, and Internet of Vehicles. Therefore, the basic needs of machine communications for 5G networks are massive terminal access, ultra-low delay, efficient connectivity, low cost, low power consumption, ultra-high reliability, and full geographic coverage.

MMC Architecture

The massive machine communication (MMC) network structure includes terminal-side, access side, core network side, and service side network layers. Technology upgrades or innovative technology needs to support all network layers. At the terminal layer, device-to-device (D2D) technology is used for multi-hop access networks or for transmitting data directly between terminals to optimize network resources and cover the entire network. Networks can also be built at the terminal layer and can be connected to 5G networks through IoT terminal gateways. At the access side, small-cell access, ultra-dense network (UDN) access, service gateway, downwards movement of the forwarding plane and multi-RAT collaboration technologies guarantee ultra-low-delay transmission and massive terminal access. At the core network side, NFV and SDN technologies make all network functions and applications operate as virtual machines and schedules network resources dynamically. Moreover, a unified control plane is used for centralized control. At the forwarding plane, data flow can be forwarded according to the flow meter, and service applications can be provided through service chains.

Massive Terminal Access Technology

The 5G era will witness both rapid evolution of machine-to-machine (M2M) communication and explosive growth of terminals connected to 5G networks. It is imperative to improve the terminal access mechanism. On the one hand, improving access capacity to connect massive terminals and provide high-bandwidth traffic guarantees user experience and satisfaction. On the other, machine terminals have various requirements, such as services (including video, voice and data flow), priorities, mobility and real time. Therefore, differentiated wireless resource control and mobility management are needed to maximize the use of network resources.

PRACH Preamble Enhancement

The MMC system should satisfy the access demand of massive terminals first. The random access scheme in existing LTE systems derives from Slotted-ALOHA. If it is used in an MMC system, more random access resources (time, frequency, and codes) can be allocated to MMC terminals. However, the allocation of many time-frequency resources to random access channels limits the bandwidth for terminal service transmission, which affects user experience and system spectral efficiency.

Because most MMC terminals support only one or a few service types, different access channels can be divided according to the service types supported

by MMC terminals to reasonably allocate channel resources and optimize spectrum use (Table 1).

MMC services have different requirements for time delay in access networks. When many MMC terminals are simultaneously connected, it supposed to allocate different access resources in a time domain to MMC terminals. MMC services that have low delay tolerance can use the nearest access resources, and those that have high delay tolerance use further access resources. This ensures better access resources utilization and user experience.

The random-access scheme in existing LTE systems assigns random access codewords from orthogonal Zadoff-Chu sequences to terminals. However, due to the impact of multi-path delay and Doppler frequency domain on channels, it can be detected on the receiver side that random access codewords are not completely orthogonal but have mutual interference, which becomes higher and more obvious when more terminals initiate random access requests. In addition, this interference is affected by the transmit power of terminals. Therefore, an interference-cancellation technology, such as successive interference cancellation (SIC), needs to be introduced to eliminate interference and increase the number of multiplexed MMC terminals.

Random access codeword resources available in a cell can be allocated flexibly according to MMC network load, and multiple cells can share their random access codeword resources with each other (Fig. 1). Cell A, Cell B, and Cell C on an MMC Network can use three times more codeword resources than those on traditional networks, which further reduces the access delay caused by the collision of codewords. From above, a multi-cell cooperation mechanism should be established for random access codeword resources.

Table 1. MMC terminal service types (partial).

Service Type	Instance	Delay Tolerance Level	Number of Concurrent Services	Service Triggering Interval
1	Telemedicine	Low	Few	Long
2	Traffic management and control	Low	Many	Short
3	Smart metering	High	Few	Long
4	Disaster monitoring	Low	Many	Long

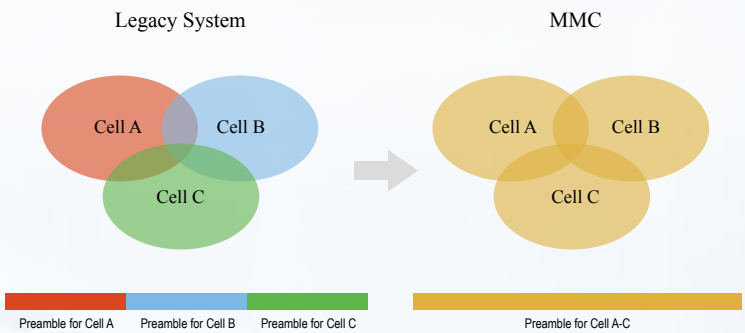


Figure 1. Multiplexing of random access codeword resources.

Control Plane Consumption Optimization

Massive connected terminals bring not only tremendous pressure on access resources but also capacity bottlenecks of service sharing channels that are used for data transmission. The bandwidth and throughput always fail to keep up with the meteoric growth of services and traffic.

4G LTE systems should guarantee the mobility of human-to-human (H2H) communication users and scheduling flexibility, the control channels may occupy up to 20% of the total data bandwidth, which is quite large. Therefore, an important research

direction in the 5G era is to reduce the consumption on the control plane and expand data transmission pipes. The scheduling consumption of downlink control channels and consumption of uplink control channels can be reduced, and air interface signaling and signaling on the ground side can be simplified.

Generally, each downlink resource scheduling instruction dispatches a single-user transmission. The cost is acceptable if data traffic transmitted at one time is very large. However, the cost effectiveness of many MMC services is too low because of low data traffic transmitted each time. The following methods can be used to enhance the efficiency of scheduling instructions by allowing a single instruction to have greater scheduling capacity.

- Multi-user scheduling: An instruction is used for scheduling a single transmission of multiple users.
- Integrated scheduling of multiple data packets: Multiple data packets are integrated and transmitted rapidly, reducing scheduling instructions and resource fragments.

Most MMC services do not transmit data frequently. After MMC terminals have been connected to networks, the current 4G LTE networks need to maintain a set of uplink control channels for each user to ensure that users can always quickly apply for uplink transmission resources from the network side. H2H users use uplink control channels frequently whereas MMC users barely use those channels. To increase the utilization of uplink control channels for MMC users, multiple users can share uplink control channels through time-division multiplexing (TDM). If a user does not need to upload data, the uplink control channels can be temporarily used by others.

MMC users require lower mobility than H2H users. The focus of research on MMC services in the 5G era is simplify signaling processes because most MMC terminals are fixed at certain positions. With the large terminal cardinality, even slight signaling simplification saves enormous bandwidth resources. In addition, MMC terminals in fixed positions do not need to repeat uplink synchronization procedures and therefore signaling related to uplink synchronization in conventional 4G random access procedures can be simplified.

Ultra Real Time Technology

Delay is a key factor that affects end user experience. In the current LTE Release 8 networks, the typical round-trip time (RTT) for internet access between end users and servers is 30–60 ms (10–20 ms in an ideal laboratory environment). To meet the application requirements of intelligent industry, intelligent transportation, smart grid, and smart healthcare, super-real-time communications with a delay of 1 ms has been proposed. It is one of the challenges facing next-generation wireless communications.

Ultra-Real-Time Frame Structure

In *A 5G Wireless Communication Vision*, TU Dresden proposed the decomposition of an ultra-low time delay of 1 ms in 5G systems, with only 200 us used for baseband modem and air interface processing. In order to achieve a delay of only 1 ms under the frame structure of the existing communication systems, the modules at the top and physical layers on both the sender and receiver sides should be optimized.

In an LTE system, if the transmission time interval is 1 ms, the corresponding RTT is about 8 ms. In a 5G system, the RTT should be less than 200 us to reach the delay of 1 ms. Assuming the capacity of transmitters and receivers can be comparable to that in the existing LTE system, the air interface transmission time interval in the 5G system should not exceed 25 us.

Scheduling Optimization

To transmit uplink data in an existing LTE system, a UE should send a scheduling request first. The base station receives the scheduling request and transmits scheduling information to the UE. After receiving the scheduling information, the UE transmits data through related resources according to the instruction. To reduce the scheduling request delay and scheduling delay for uplink data, self-scheduling is recommended. That is, some resources are allocated in advance. The UE can transmit data directly through pre-allocated resources without sending scheduling requests or waiting for scheduling by the base station. By doing so, the time delay can be reduced to increase data transmission efficiency.

The UE's demand for data transmission is dynamic; some of the pre-allocated resources may idle, resulting in decreased system spectral efficiency. In this case, code-division multiplexing (CDM) allows multiple users to reuse the same time-frequency resources to maximize resource utilization.

Efficient Connection Technology

Large-scale machine terminals are using 3G or 4G communications. The frequent transmitting of small data packet by machine terminals leads to frequent access control signaling between RAN and CN. Accordingly, the ratio of control signaling traffic to total traffic increases, and transmission efficiency is reduced.

An efficient connection design for 5G systems can satisfy the needs of MMC small data. Improving the transmission efficiency of small data packet is a way to achieve efficient connection. If common air interface technology is used to transmit small data packets, air interface resources are wasted. 5G systems require a more efficient air interface design where the granularity of the air interface resource scheduling can be adjusted according to the features of small data packets. The concept of integrated scheduling of multiple packets mentioned above can be used to improve resource utilization efficiency.

To improve the air interface efficiency in 5G networks, new air interface technology can be used to optimize bandwidth design, achieve the interaction of small data signaling and transmit small data packets. In addition, the existing bands can be shared. Some 4G frequency can be allocated to transmit MMC signaling and small data packets. FDM/TDM technology and the overload system technology can be used in 3GPP networks and 3GPP2 networks, respectively.

As for improving the signaling efficiency, signaling interaction between the RAN and CN should be reduced when terminals frequently transmit small data packets to shorten end-to-end transmission delay. The access control function of MME can be moved downwards to the RAN side. In the case of frequent access of terminals, the RAN can implement access control and allocate wireless resources without access control signaling interaction with the control plane NEs on the CN. It also can interact with the user plane NEs to implement bearer establishment and transmit small data packets. On the user plane, the forwarding plane can also be moved downwards to the RAN side, and data interaction with application platforms can be implemented directly through forwarding plane.

Conclusion

5G will open a new era of IoT—a new-generation network system based on the internet. New-generation 5G networks will provide wireless connection for diversified network devices, handle all networking information at an extremely high speed, and achieve efficient, convenient and secure information transmission and sharing. ZTE TECHNOLOGIES

Ultra Dense Network in 5G

By Hao Peng

Outline of UDN

Recent years have seen tremendous growth in mobile data traffic, and this trend is expected to continue in the near future. To cope with this growth, dense transmission points (TPs), e.g., ultra-dense networks (UDNs), need to be deployed. Fig. 1 shows six typical UDN scenarios identified by the IMT-2020 (5G) Promotion Group (China).

Cell-Edge Effect

Densifying TPs creates many

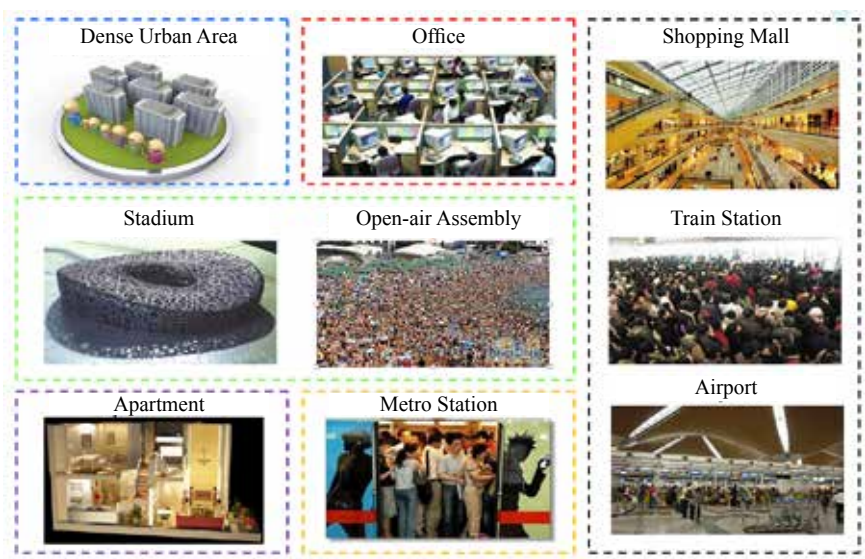


Figure. 1 Typical UDN scenarios.

Smooth cell virtualization with hybrid control is an effective way to deal with mobility and interference issue for UDN.

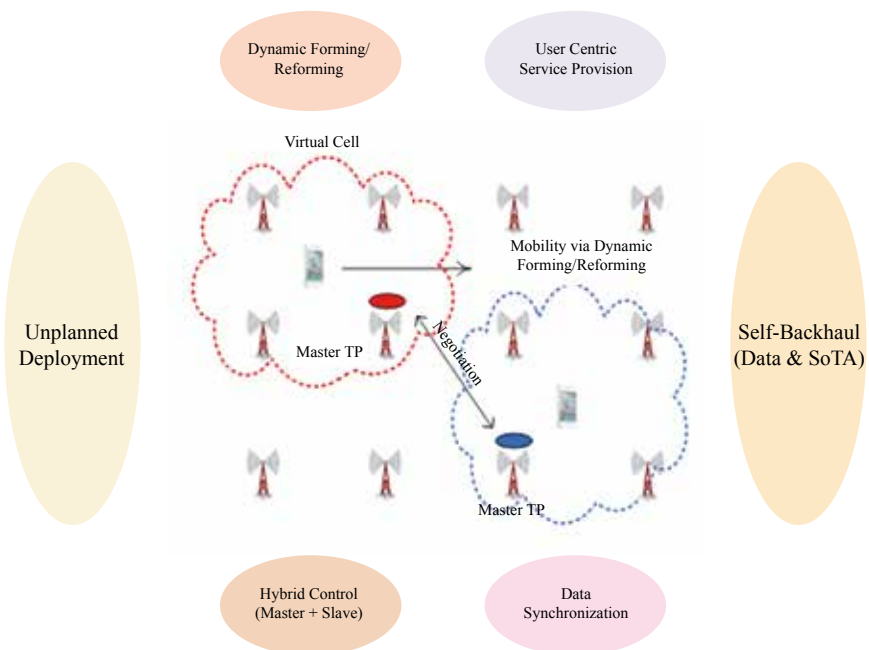


Figure 2. Smooth cell virtualization.

challenges, such as cell-edge effect, where mobility and interference are negatively affected. CoMP in LTE, soft handover in CDMA, and fast cell selection in WiMAX have been proposed to address this issue. However, they may not work well in a future network, and deploying a dense small cell network with ideal backhaul becomes more and more difficult. Therefore, the idea of smooth cell virtualization with hybrid control mechanism is proposed. It is an effective way to deal with mobility and interference issue for UDN.

What is Smooth Cell Virtualization?

Fig. 2 shows smooth cell virtualization. Several TPs around a user form a smooth virtual cell (SVC) to provide user-centric service. One master TP is selected to control working procedure of the corresponding SVC. Master TPs between different SVCs negotiate with each other on resource allocation so as to enable harmonious coexistence of different SVCs. Because TPs involved in the control circle are in proximity, fast control for dynamic forming/reforming of SVC and negotiation are possible. In addition, signaling via self-backhaul or signaling over the air (SoTA) can further reduce latency on control signaling and make the virtual cell more efficient.

Benefit of Smooth Cell Virtualization

Simulation shows the effectiveness of a uniform user experience. The red curve in Fig. 3a shows the cumulative distribution function (CDF) of downlink SINR of a UE in different locations without user-centric service provision. The SINR ranges from −1 dB to 22 dB, and the user has a very different experience in different locations. The blue curve in Fig. 3a shows the CDF of downlink SINR with user-centric service provision. If user-centric service is provided via cell virtualization and TPs are dynamically muted at the desired resources of a target UE, SINR can be kept to a target level of about 17 dB as it moves around. Gain from interference mitigation via SVC is shown in Fig. 3b.

Devices are also expected to be

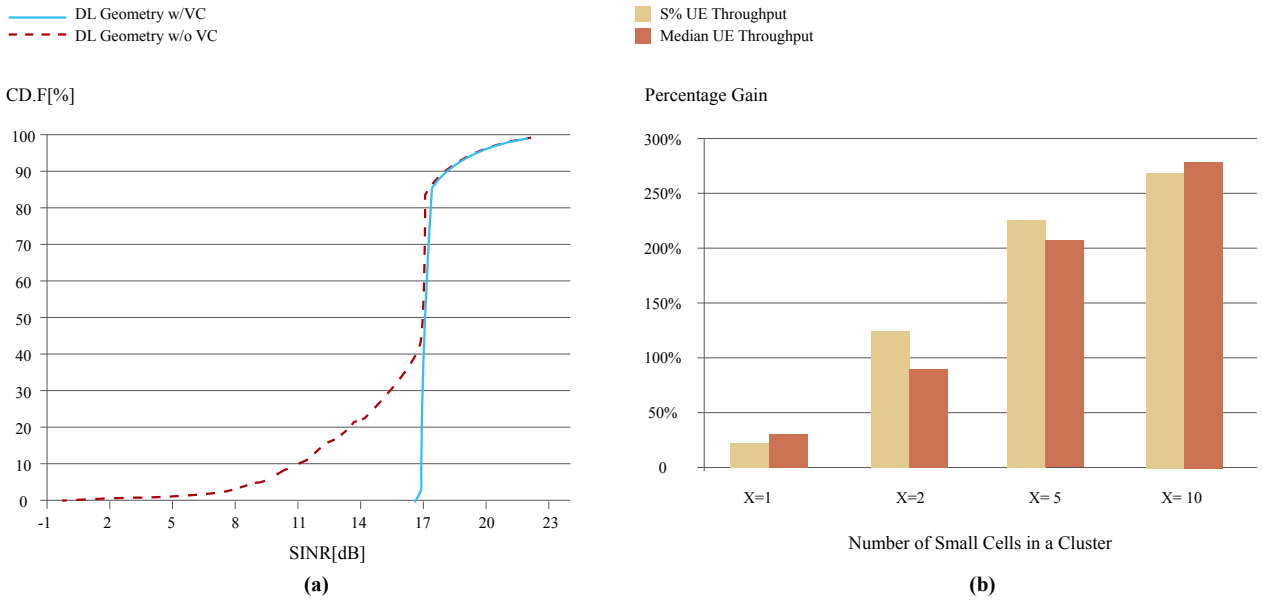


Figure 3. Performance of smooth cell virtualization.

densified in the future. Recently, wearable devices have become popular. Users may own more than one device with demand for data connection and supporting direct communication among devices. Multiple devices can be grouped as a virtual user. Virtualization on user terminals can also mitigate interference and simplify resource allocation on the network side.

Self-Backhaul

Backhaul is another key issue associated with the increased cell density. Self-backhaul is cost-effective because it doesn't require any cable connection but supports unplanned or semi-planned deployment as well as spectrum and RAT sharing with access link. Moreover, self-backhaul ensures link quality by using licensed spectrum and joint optimization with access link. Self-backhaul nodes can also provide traffic offloading and prominent cell split gain in densely deployed networks by applying content prediction and caching techniques.

There are many potential enhancements to self-backhaul. MIMO is a powerful method for increasing link efficiency of self-backhaul by exploiting additional spatial degree of freedom or diversity gain. A scheme exploiting massive MIMO is studied and remarkable gain can be observed. Joint resource allocation and optimization between the backhaul link and access link is an attractive way of increasing radio resource efficiency and self-backhaul capacity. Flexible resource allocation between uplink and downlink can also be considered to make full use of radio resource by exploiting the feature of uplink and downlink traffic fluctuation.

Besides high capacity, the design of UDN should also consider other 5G requirements, such as content diversity, low-latency highly-reliable communication, and massive machine communication. How to coexist with mmWave and eSON and to exploit output from the IT field is worthy of in-depth study. Making full use of millions of WiFi APs via multi-RAT and intelligently mapping content between different RATs will significantly enhance network performance.

Conclusion

UDN is an important way that operators can meet the 5G requirement on data volume per area. ZTE has proposed smooth cell virtualization and self-backhaul to solve problems such as cell edge effect and flexible deployment in UDN and delivers an efficient ultra dense network with fantastic user experience. ZTE TECHNOLOGIES

A Discussion into Massive MIMO

By Yi Qiao and Wang Xiaopeng

With the evolution of wireless communication technology, high-speed data services and ubiquitous access are undergoing explosive growth. It is estimated that by 2020, service traffic will grow 1,000 times compared with current service traffic. To meet users' service requirements, we need to improve the capacity of wireless broadband access networks.

To target the needs of wireless broadband access, the European Union, China, Japan and United States have already started research into the requirements and key technologies of 5G mobile communication systems. The upgrade from 2G and 3G to 4G always comes with the emergence of new technologies and aims to solve the primary needs at the moment. In the post-4G era, cells will become denser and demands for capacity, energy consumption, and services will increase. The following ways can be used to improve network throughput: increase the transmission rate of point-to-point links; expand spectrum resources; deploy high-density heterogeneous networks.

As data traffic develops, multi-antenna technologies, such as 8-port MU-MIMO and CoMP, in existing 4G cellular networks are insufficient to meet user demands for bandwidth. The latest research shows that large-scale antenna arrays comprising hundreds of antennas or more can be used on a base station side to significantly improve its performance. This technology is called large-scale antenna systems (LSAS), or Massive MIMO.

Applications

Major applications for Massive MIMO include urban coverage, wireless backhaul, suburban coverage and local hotspots. Urban coverage involves

macro-coverage and micro-coverage (within high-rise office buildings). Wireless backhaul involves dealing with data transmission between base stations, especially between macro base stations and small cells. Suburban coverage focuses on wireless transmission in remote areas. Local hotspots are used for high-density areas, such as major sports events, concerts, shopping malls, open-air gatherings, or transportation hubs.

Considering the antenna size and installation, distributed antennas become pragmatic. The coordination mechanisms and signaling transmission between antennas are big considerations. In the future, the main scenarios for large-scale antennas are outdoor macro coverage, high-rise building coverage, and indoor coverage.

Table 1. Major research directions for the physical layer of Massive MIMO.

Research Direction	Difference from Traditional Antennas	Priority
Base station antenna structure design	Antennas are arranged on two-dimensional planes/surfaces or in three-dimensional arrays.	Medium
Base station precoding	New precoding algorithms should be explored.	Medium
Base station signal detection and channel estimation	TDD systems are not affected, while FDD systems need new feedback algorithms.	Medium
Control channel performance improvement	The coverage capacity of control channels is much lower than that of data channels.	High

Research Directions

Massive MIMO is also called large-scale MIMO. With Massive MIMO, hundreds of antennas (128, 256 or more) are installed on a base station to transmit data simultaneously.

Under MAC+PHY structure of the existing LTE systems, main research directions for the physical layer of Massive MIMO include base station antenna structure design, base station precoding, base station signal detection and channel estimation, and control channel performance improvement (Table 1).

As the number of antenna elements increases sharply, these elements need to be expanded to two-dimensional planes/surfaces or three-dimensional arrays. Should an omni-directional (spherical) antenna array, or a planar (plane-shaped) antenna array, or any irregular-shaped antenna array be chosen? This needs to be studied carefully. Meanwhile, although there are a large number of antennas, only larger antenna arrays can match the isolation. Consequently, the usage of higher frequency bands (> 5 GHz) is one of the research topics.

An increasing number of antennas leads to larger antenna dimensions, which causes larger near-field deviation in case of channel modeling using the traditional plane wave method. Therefore, appropriate channel modeling needs to be chosen.

In addition, the transceiver mode for active antennas to be used by MIMO has already been applied in LTE systems.

The performance of massive MIMO will remain stable as the number of antennas is increased. In this case, multi-user MIMO (MU-MIMO) can be adopted. The key to MU-MIMO technology is precoding. Currently, major precoding technologies include MRT, ZT and DPC, among which DPC is considered to be the best and MRT the worst. It is important to find appropriate precoding algorithms; for instance, the ZF algorithm is generally used in engineering. Whether we can find new precoding algorithms with high complexity and performance is a crucial issue at the physical layer.

Compared with traditional MIMO,

the channels of Massive MIMO tend to be orthogonal when many antennas are involved. Most system performance is related only to the large rather than the small scale. The pilot design of hundreds of antennas in a base station costs lots of time frequency resources, so pilot-based channel estimation is not advisable. Specific solutions are implemented in TDD and FDD modes, where TDD has intrinsic advantages and is preferred. As the number of antennas is increased, the consumption of CSI-RS is also increased, In TDD mode, channel estimation can be conducted based on channel reciprocity without using pilots. In FDD mode, with wide coverage and high popularity, codebooks with lower consumption can be used for channel coefficient estimation and feedback, and compressive sensing (CS) algorithm can be used for channel feedback. Therefore, channel detection, estimation and feedback cannot be neglected.

After the number of antennas is increased, service channel coverage can meet user requirements, but the capacity of control channel is not enhanced. Accordingly, control channel coverage will become a bottleneck to system performance.

The main MAC research directions for Massive MIMO include MU-MIMO matching algorithms, user scheduling, and resource allocation strategies.

Massive MIMO involves numerous antennas and the channels between multiple users tend to be orthogonal, so the same time frequency resources can be used for user data transmission. When MU-MIMO is used, the base station simultaneously sends data to multiple users, the actual transmission power obtained by each user decreases sequentially. Lower power causes performance loss. Then it is crucial for Massive MIMO to determine which users are suitable for matching and what kind of matching optimizes system performance.

The spacing is bigger when the antennas are far apart. In order to improve system capacity by fully utilizing the antennas, some antennas are allocated to user A and others to user B. This is the allocation strategy for user antennas.

Transmit antennas can simultaneously send data to one or more users, which is RB resource allocation strategy. At present, the traditional resource allocation method can be used if it matches the user retransmission strategy.

What's more, Massive MIMO can be used together with other networking technologies, such as CoMP technology in LTE systems.

Conclusion

Massive MIMO is a key technology for 5G. It solves core problems in the PHY and MAC layers. The main research topics on Massive MIMO are closely associated—we should determine the antenna configurations and frequency bands for Massive MIMO, select appropriate methods for channel modeling to conduct the follow-up research, implement rational precoding design as well as rapid and effective channel detection and estimation, and improve control channel performance. Moreover, depending on the scenario and application, we should select appropriate MU matching algorithms and antenna segmentation or distributed antenna allocation methods for scheduling and allocating physical resources to enhance system performance. ZTE TECHNOLOGIES

ZTE HELPS CHINA TELECOM INCREASE ITS 4G CORE COMPETITIVENESS

By Huang Xuan and Li Qianghua

LTE networks were widely deployed in China in 2014. According to IHS statistics, in 2014, LTE deployment in China accounted for 54% of all worldwide LTE deployment. China's three main operators—China Mobile, China Telecom and China Unicom—have all played an important role in the 4G era despite having different 3G standards. However, China Telecom stands out because of its advanced 3G CDMA network.

Global mainstream CDMA operators such as Verizon, KDDI, Sprint, and LGU+, have seized the opportunity to develop LTE networks to enhance their network competitiveness and make up for their weaknesses in 3G. They have become the world's leading LTE operators. The experience of these global LTE network deployments can be summarized as follows:

- full coverage. They have rapidly transitioned from being leading 3G operators to being leading 4G operators.
- new technology application. They have improved new service deployment capabilities to stimulate LTE user activity.
- industry chain optimization. They have gradually shaken off the CDMA industry constraints and snapped rapidly into the global LTE industry chain.

China Telecom can learn from the experience of other mainstream LTE operators to improve its 4G core competitiveness and establish a leading 4G brand in China.

Expanding Coverage

Small cells are installed and deployed flexibly and can be used for a variety of coverage scenarios. ZTE boasts a full range of LTE eNBs, including outdoor distributed and integrated eNBs, indoor enterprise distributed and integrated eNBs, and even low-power home eNBs. These eNBs meet China Telecom's requirement for LTE coverage in different scenarios. ZTE's LTE eNBs have several backhaul modes, including direct connection through optical fibers, CAT-5 cable connection, and even FTTH. These backhaul modes leverage China Telecom's transmission advantages.

At PT/Expo Comm China 2014 in Beijing, ZTE officially launched its industry-leading 4G Qcell solution for intensive indoor coverage. This is the world's first 4G active-distribution solution supporting multi-frequency and multi-mode network deployment. It converges an operator's networks for superior indoor performance. Unlike traditional DAS solutions, ZTE's Qcell solution involves the use of standard Ethernet cables for Pico RRU network construction and power supply. This reduces construction cost and complexity, reducing deployment time by 60%. ZTE's 4G Qcell also uses cell-combining technology to balance capacity with coverage. ZTE's

transmission compression algorithms and patented multimode integration technologies aggregate two 20 MHz carriers for an LTE cell through an Ethernet cable or provide CDMA/LTE wireless systems through an Ethernet cable. This greatly reduces complexity of multimode indoor coverage networks. In addition, the Qcell and macro eNBs share a network management system, where each node is visible, controllable, and manageable, significantly reducing operation and maintenance costs.

"ZTE's 4G Qcell solution provides end-users with ubiquitous access to a superior network, both indoors and outdoors, and satisfies demands for both network capacity and service coverage in the 4G era," said Zhang Jianguo, vice president of ZTE. "The new technology from ZTE outperforms existing solutions on the market, giving operators the advantages of large capacity, seamless coverage, rapid deployment, smooth evolution, manageability, and controllability."

Enhancing User Experience

Enhancing user experience involves maximum download rates and smooth speed experience.

Carrier aggregation (CA) is the most effective means of improving peak rates. ZTE has led the LTE-A technology. Early in June 2013, ZTE demonstrated the aggregation of four carriers at the Mobile Asia Expo in Shanghai, with the rate reaching up to 1 Gbps.

Smooth speed is largely affected by data rates at the cell edge. To increase cell edge rates and offer smooth user experience, ZTE proposed Pre5G in which 5G RAN is based on IP transmission and forms a dynamic mesh network. In the mesh network, there are various base stations, such as small UDN, massive MIMO, traditional macro, and D2D. Horizontal collaboration between the various base stations is more frequent than in a 4G network. To adapt to user mobility and moving networks, the mesh network must be dynamic and adaptive. ZTE's cloud radio is an adaptive technology for dynamic collaboration between base stations. The technology has been field tested in China Telecom's commercial 4G network and will be gradually used on a larger scale. Test results show that cloud radio can increase the rate of cell-edge users by more than 80% and greatly enhance user experience.

Improving the Industry Chain

To remove CDMA functions from terminals and migrate all services, especially voice to LTE, it is necessary to build an LTE network that provides full coverage. China Telecom's LTE network uses the 1.8 GHz band in the early stage, with its coverage capacity much lower than that of the 800 MHz band in 2G and 3G networks. Since there are far from enough existing base stations for full coverage, many base station sites must be deployed. However, the return on investment in deploying base stations in rural areas is relatively low. Therefore, the low 800 MHz band with better coverage needs to be considered for low-cost LTE deployment in rural areas.

To meet China Telecom's requirements in rural areas, ZTE has proposed a CDMA2000/LTE dual-mode base station solution. This solution significantly reduces construction and maintenance costs for rural coverage. It is easy to deploy and can even be deployed on existing 2G/3G networks simply by adding LTE baseband boards. There is no need for extra radio frequencies or antennas. This solution helps China Telecom save more than 90% of deployment cost and time for a single base station. "ZTE was the first to launch its CDMA/LTE multimode solution in 2009 and also the first to demonstrate the solution at the CTIA shows in Japan and America. Now the solution has proved successful, and ZTE has led the industry in this regard," said Liu Jinlong, vice president of ZTE.

ZTE is China Telecom's trusted long-term strategic partner. Drawing on its innovative and pragmatic commitment and cutting-edge technologies, ZTE is building a competitive high-quality 4G network tailored to meet China Telecom's expectations. ZTE TECHNOLOGIES

ZTE'S DAP CONTRIBUTES TO PERFECT PERFORMANCE OF NANJING YOG

By Huo Jie

On August 28, 2014, the Nanjing Youth Olympic Games (YOG) that lasted 12 days came to a successful close at the Nanjing Olympic Sports Center. Thomas Bach, president of the International Olympic Committee, praised the Nanjing YOG as "perfect" in his speech. Three thousand seven hundred and eighty seven athletes from 204 countries participated in the Nanjing YOG, which is one of the sports events involving the largest number of countries and regions. To undertake such an international event, various departments in Nanjing made an all-out effort to collaborate with each other, especially in the areas of security and traffic control. The Nanjing Public Security Bureau worked with ZTE to develop the "Moat of Nanjing" system, which guaranteed the Nanjing YOG ran smoothly.

Thomas Bach, president of the International Olympic Committee

One of the challenges of holding an international event is easing traffic flow in order to guarantee its safety and efficiency. This problem is especially complicated in such a populous country as China. The data in the transportation industry is extremely complex, involving mutual dependence and interaction between four major factors: people, vehicles, roads and environment. In addition, the data in the transportation system is dynamic; they should be compared and analyzed in real time so that emergencies can be handled immediately. Therefore, high data storage, calculation, analysis and processing capabilities are requested for

the transportation system.

The "Moat of Nanjing" is a customized public security platform based on ZTE's data analysis platform (DAP), implements real-time statistics and presentation of people and vehicles. It also provides comprehensive, convenient, and efficient data support and management for dispatching, analyzing personnel, and vehicle information management. During the Nanjing YOG, the number of visitors increased 20%, and the peak number of non-local cars increased 200%. Nevertheless, because of traffic control and planning, even the traffic in Xinjiekou, the most prosperous area in Nanjing, was 30% less than usual, indicating the advantages of ZTE's DAP.

In addition to the large quantity and high complexity of data, short development cycle and various data sources imposed severe challenges to ZTE during the construction of the "Moat of Nanjing." However, thanks to the great efforts of ZTE's project team, the scattered data was integrated into the big data platform and the project was successfully delivered within two months. Moreover, the "Moat of Nanjing" system operated stably during the Nanjing YOG and was highly praised by Jiangsu Provincial Public Security Department and Nanjing Public Security Bureau for its timely and accurate data reporting, intuitive data statistics, and convenient retrieval capacity.

Based on the Hadoop system, ZTE's DAP integrates core Hadoop components to provide complete big data storage and management capabilities for urban operation and management systems (Fig. 1). It has a wealth of data extraction tools to extract, clean, and dump structured and unstructured data. It also provides powerful data analysis and mining tools and integrates, improves, and optimizes popular open-source tools to support upper applications. With multiple data presentations, such as reports and GIS, ZTE's DAP provides a variety of system access methods. With fully functional management tools, ZTE's DAP supports platform manual and silent installation, achieving platform monitoring and management.

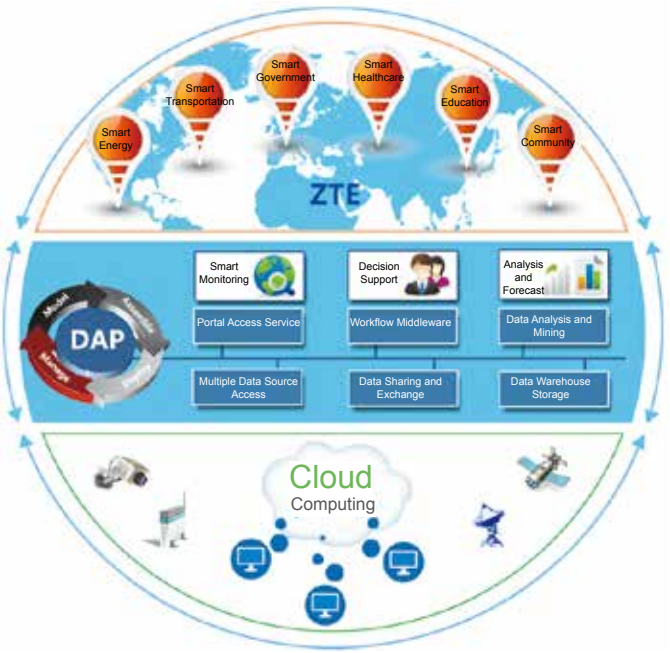


Figure 1. Application of ZTE DAP big data platform in smart city.

The "Moat of Nanjing" system is just an application of ZTE's DAP, which can play an important role in even more sectors due to its flexible architecture. The key management components of ZTE's DAP can be integrated seamlessly into existing IT systems and can rapidly build various big data platforms as well as provide diversified system applications to meet different service needs. In addition, universal platform software, such as distributed file systems and distributed database cloud storage, can be used to increase the massive data query speed, reduce database construction costs, and improve storage resource utilization and reliability. ZTE creates great data value for its customers through efficient data utilization, powerful data mining and analysis capabilities, and professional data security guarantee.

As a leading provider of smart city solutions in China, ZTE is committed to smart city construction and research and has formulated all-round smart city solutions from top-level design to network infrastructure construction. The successful "Moat of Nanjing" project at the Nanjing YOG has set a new milestone for the application of ZTE's big data solutions in the public safety field, and laid a solid foundation for further development of big data products.

In the future, ZTE's big data solutions will have wider application in smart energy, smart transportation, smart government, smart healthcare, smart community, and smart education. With the advanced information technology of smart city, ZTE will make cities better places. ZTE TECHNOLOGIES

Global LTE Market Analysis

Q1 2015
Source: IHS research paper

Executive Summary

From the first investment wave in 2009, LTE has achieved global success thanks to the contributions from each link of the entire industry chain. More carriers revised their view from LTE island coverage at hotspot areas to nationwide coverage and turned LTE into a key differentiator with other WCDMA operators.

GSA reported that 360 commercial LTE networks launched in 124 countries by 2014, which including 48 LTE TDD networks in 30 countries, there are 17 operators deploying both LTE FDD and TDD networks among the 48 LTE TDD networks. LTE handset was much stronger than 2013, a total of 183 manufacturers released 2,218 devices by Oct 2014. The number of LTE subscriptions amounted to 480 million by the end of 2014 and is estimated to exceed 850 million by the end of 2015.

Deployment of LTE-Advanced (LTE-A) was a main trend in 2014 in developed countries, GSA reported that 107 operators are investing in LTE-A in 54 countries including 49 commercially launched LTE systems in 31 countries. Voice service is a mandatory service on LTE networks, GSA reported that 80 operators in 42 countries are investing in voice over LTE (VoLTE) including 14 commercialized VoLTE networks, there are 146 smartphones supporting VoLTE as of 2014.

In 2014, the LTE rollouts in China

> *ZTE's LTE BTS shipments maintained rapid growth for two consecutive years and the year-on-year growth rate increased up to 133% in 2014.*

had a tremendous impact on the total global LTE market. ZTE and Huawei benefited a lot from China telecoms' bidding, while ALU, Ericsson and Nokia were awarded limited shares. On the whole, IHS estimates that LTE shipments reached 1,036 thousands of eNodeBs globally. Huawei (25.2%), ZTE (24.8%) and Ericsson (14.5%) were ranked as the top 3 of the LTE BTS vendors in 2014. It was the first year that Chinese domestic vendors outpaced Ericsson in the LTE market. ZTE's LTE BTS shipments maintained rapid growth for two consecutive years and the year-on-year growth rate increased up to 133% in 2014, following 2013 to continue to maintain the fastest growing company with 6.6 pts share increase in 2014.

In terms of FDD LTE market, Ericsson and Huawei are the top 2 vendors. Furthermore, ZTE acted as the fastest growth vendor in 2014. The company aggressively broke through around 14 new markets in Europe, South America and Asia regions, and its FDD LTE BTS shipment amounted to more than 100,000 units in 2014.

Huawei and ZTE are the top 2 of the TD-LTE BTS infrastructure vendors, and their market share and product solutions are far leading their rivals in the round. ZTE shows excellent growth that is better than its competitors in the TD-LTE market. The company obtained the first position in China TD-LTE market in the past consecutive two years; and moreover, ZTE rapidly expanded into the global TD-LTE market to win lots of deals in Japan, India, Indonesia, Russia and Brazil, etc.

We estimate that the global LTE investment will grow 18% in 2015 and decline from 2016. North America will decline due to that most carriers completed LTE coverage, LTE investment in Asia Pacific will grow in 2015 but start to decline in 2016 due to Chinese operators accelerating LTE rollout progress, the Europe Middle East and Africa market will keep growing by 2016.

China LTE market will keep playing a dominate role in 2015. We estimate that China Telecom and China Unicom will be awarded nationwide LTE FDD licenses, and China Mobile will enhance its TD-LTE coverage in the third year which also is the last year of massive LTE deployment. We estimate three China operators will deploy over 800 thousands of eNodeBs in 2015, which will be a great opportunity for ZTE and Huawei to consolidate their LTE market leading position in the world.

Evolved packet core (EPC) market will remain flat and slightly increase, IHS estimates that total sessions shipments of EPC will reach 4,665 billion in 2019. The EPC market contributed 55% to the total mobile packet core market in 2014, and is expected to reach 70% in 2019.

In 2014, ZTE acted as the fastest growing vendor and its EPC revenue increased by 196% year over year in Europe. Up to 2014Q4, ZTE EPC product has won over 70 commercial contracts in extensive partnerships with mainstream operators such as China Mobile, China Telecom, Vodafone, KPN, Telenor, TeliaSonera and Hutchison. Meantime, ZTE IMS product has won over 170 commercial/trial contracts worldwide.

Before 5G, ZTE is promoting its Pre5G to enable end-users to enjoy 5G experiences with current 4G handset, and ZTE has competed Pre5G field trial with China Mobile and a Japanese tier one operator. Huawei also announced its 4.5G concept which will be commercialized in 2016.

Small cell will play an important role to expand LTE network capacity, especially for indoor coverage. ZTE's Qcell, Ericsson's Radio DOT system and Huawei's Lampsite are competitive and flexible solutions to match customer requirements.

From a 2G/3G/4G convergence point of view, ZTE's magic radio is designed to deploy LTE with current GSM networks in the 1,800 MHz spectrum simultaneously. On the other hand, ultra broadband radio (UBR) is another RRU product to combine a legacy 2G/3G product with LTE.

IHS believes NFV will occupy a portion of existing capex for network infrastructure. IHS expects a limited number of carriers to move from demos and proof-of-concept (PoC) testing to trials and early commercial deployments of NFV in 2014 and 2015 before wider deployment starts in 2016. All of the infrastructure players, Huawei, ZTE, Ericsson, ALU, Nokia and Cisco, have announced their NFV solutions in the past year. ZTE is the pioneer vendor on NFV technology with roughly half of its NFV portfolio commercially available and half under development. ZTE TECHNOLOGIES


ZTE
Tomorrow never waits