INTERVIEW

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Wen Tong: 5G will be the neural network of the physical world

By Weijie Zhao

Smart phones, video, computer games, social platforms and mobile payments have dramatically changed our daily lives in the past 10 years. Behind the rise of the internet industry, fourth-generation (4G) network technology played an instrumental role. According to the plans of major communications companies and the global standardization organization 3GPP (3rd Generation Partnership Project), the next generation of wireless network technology (5G) will start to be commercially used before 2020. What will be the technological improvements in performance of 5G comparing with 4G? Would 5G be similarly transformative? In a recent interview with NSR, Huawei's Chief 5G scientist, Wen Tong, talked about these topics, as well as about the transformation of China's communications industry from a technology follower in the eras of 3G and 4G to one of the leading forces behind 5G.

FROM 1G TO 5G

NSR: How have mobile telecommunications changed in the past several decades?

Tong: I would like to start with the history of the communications industry. Typically, for mobile communication, the technology would evolve a new generation every 10 years, with a consequent leap in both wireless technology and mobile applications each time.

From 1G to 2G, voice communication was transformed from fixed-line telephones to mobile (cell) telephones. This was a success of digital wireless communication technology. We spent 80 years to build the fixed-line network and to install fixed phones into every household. But mobile phones became pervasive in only 20 years. That is the power of technology.

Then with 3G and 4G we began to use wireless technology for data communication, and were no longer limited to just phone calls. 3G brought about the jump from voice to data. When we started to design 3G systems in the 1990s, no one quite understood how the internet was going to evolve. So many potential applications, such as video calls, were not successfully introduced with 3G. After the first version of 3G was deployed, personal computers became popular and Internet Protocol (IP) technology became mainstream. And when smart phones appeared, mobile communication technology found its way to 4G.

Generally speaking, 4G has accomplished only one goal: to transfer everything that is possible on the internet to the smart phone. When 4G standards were completed, we did not know that there would be the innovations like Facebook, Uber, Wechat, Twitter and Instagram. These internet applications could not achieve their current level and economic scale without 4G. As one of the 4G standards constitutors, I would say that only when communication technology and the right applications meet with each other can big economic benefits and real changes come.

NSR: What are the things 5G can and 4G cannot do?

Wen Tong, Huawei's Chief 5G scientist, IEEE Fellow, Fellow of Canadian Academy of Engineering *(Courtesy of Wen Tong).*

Tong: Well, people asked similar questions in the time of 3G and 4G. But it's difficult to predict the applications that will arise after the deployment of the 5G network—such new applications are unimaginable at this moment. However, we can still give a general vision of the technology.

There will be three main technological improvements in 5G. The first one is ultra-fast access speeds. 5G's peak speed is comparable to the speed of optical fiber transmission. This goal has already been achieved in our tests, with a speed of 115 Gb per second. The second one is massive connections. 5G is able to connect everything, including the water bottle in front of us right now, onto cloud computing in data centers. This is the concept of the ‘internet of things’, or of a ‘super-connected world’. And the last one is lower latency, which is able to eliminate the limit of distance, making it possible to communicate with every corner of world as if there is no distance between them.

With this superior performance, we can do many things. For instance, remote-controlled self-driving of vehicles. We can use sensors on the car to collect information, and transfer the information to the cloud with 5G networks. Then cloud computing can create commands that are transferred back to the car through 5G. Human participation is completely unnecessary in this whole process. If we use the current 4G network to perform it, the response distance of a car travelling at 120 km/h on the highway would be two or three meters. But if we can decrease the latency to one millisecond, which should be possible with 5G, the response distance would be lowered to eight centimeters, which would be short enough for safe driving. We will be able to do many similar things in other areas. Remote surgery will be possible. A doctor will be able to perform operations for patients on the other side of the planet. And when 5G network is deployed and the display technologies are mature, you would not need to travel from Beijing to Shanghai for this interview. We can simply transfer your image information through 5G and reconstruct your holographic image here. There will be little difference compared with a face-to-face interview—and all we need is a high-speed, low-latency network and a fast enough image-processing system.

NSR: Huawei’s white paper on 5G mentioned the concept of a smart grid. What is that?

Tong: In our vision of 5G, everything could be smart: smart driving, smart shopping, smart healthcare, smart anything. A smart grid means every part of the power grid is connected to the network, and people or computers behind the network perform analyses that control the power grid instantly. In a larger vision, 5G would be able to reshape every vertical industry.

NSR: To achieve these goals, maybe higher computing capability is also needed as well as a better wireless network?

Tong: There are three main pieces in the whole picture: all sensed, all connected and all intelligent. We use sensors to sense everything, connect everything with the network and use backstage cloud computation to accomplish the final ‘smart connection of everything’. So yes, computing is an important aspect. Before the notion of Artificial Intelligence (AI) was proposed, we used to use the word ‘automatic’. To automate everything.

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—Wen Tong”

NSR: It seems that this system is much like an animal. Our neurons sense and transfer the outside information to the central nervous system.

Tong: Well, this is a good metaphor. We sense the outside world and calculate in the brain. According to this metaphor, the neural network of the physical world is 5G.

5G TECHNOLOGY

NSR: Standardization is a very important concept in communications industry.

Tong: The ITU (International Telecommunications Union) defined a high-level framework for key performance requirements, which supplies a definition of 5G: a network could be considered to be fifth-generation only when it reaches certain speed, latency and connection standards. Beside this, there will be a detailed industrial standard provided by 3GPP, which offers a unified production standard for all cell phone and network equipment producers.

A unified global standard is extremely important for the communications industry for two reasons. First, standardization guarantees that all cell phones can be connected with each other, no matter which city or which country they are in. Second, standardization is a demand of the market; it offers the cheapest products for the consumers. If different standards are used by different smart phone makers, each company will have to independently develop every single part of the phone and the resulting products would be very expensive.

In the time of 3G, there were still several competing wireless standards. The USA, Europe and China all had their own. 4G, on the other hand, successfully achieved a single unified standard. Two or three years ago, at the beginning of the 5G standardization phase, there were divergent opinions that could have led to several fragmented standards. But now this problem has been resolved. The first version of 5G standard is ready and will be released very soon. [3GPP officially completed the first specification for 5G, the 5G New Radio standard, on 21 December 2017, nine days after this interview.]

NSR: What are the major technological innovations of 5G?

Tong: The core of wireless network technology is air interface technology, and the core of air interface technology is physical layer technology. Air interface technology is the crown of the wireless network, and the physical layer is the diamond on the crown. Physical layer technology is the foundation of information transmission: it defines how data is encoded, modulated, transmitted and then retrieved from noise and interference on the other side of the network.

To accomplish the 5G goals, the physical layer had to be drastically modified. The speed limit of information transmission for every Hertz frequency spectrum was rigorously defined by the Shannon Limit in 1948. Thanks to the efforts of generations of engineers, about 10 years ago we came very close to achieving this limit. Further improve of this speed is not easy, so at the beginning of 5G research many scholars, including several respected scientists, publically claimed that this field was already dead. A second consideration is that existing networks occupy most frequency bands, and we have to look for the remaining available frequency bands for 5G deployment. The new physical layer will be redesigned and optimized for these new frequency bands. Lastly there is the problem of implementation technologies: we have to find large-scale manufacturing techniques that are able to produce designed new smart phones and networks and to achieve easy and fast deployment.

At the earlier stage of 5G study, we searched the literature and found about a dozen raw techniques that could be candidates for the new network. Most of these works are conducted by mathematicians. The methods are not mature, though, and cannot be practically used. From 2010 to 2013, after much effort we were able to successfully reconstruct the physical layer and change these raw ideas into usable 5G technologies. After further testing and selecting these technologies, we have finally constructed the technical framework of 5G. This is not a single technology but a combination of many, including coding, waveform design, frame structure design and MIMO (Multiple-Input Multiple-Output). The new air interface technology was named New Radio (NR).

You could compare it to Fleming's discovery of a biological phenomenon in which one microorganism killed another species of microorganism. To transfer this discovery into the manufacture of the antibiotic penicillin was another thing. What we have done in creating 5G is similar to that development phase.

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—Wen Tong"

NSR: Network slicing technology is also frequently mentioned. What is that?

Tong: Air interface is the basic technology, and network slicing is a macroscopic framework. It's the structure of the network.

The structure of the network has been transformed several times. 30 or 40 years ago, each network was constructed for one specific purpose. Phone calls, telegrams and faxes were transmitted by separate networks. Then IP technology emerged, which converged everything into data packets that were transmitted through the network with equal transmission quality. However, the quality demand of different data is actually different. Important data, such as commands for automatic driving or remote surgery, calls for high-quality transmission, whereas for Wechat messages the quality requirement is relatively low. Costumers' expectation is that these messages can be transmitted at a low price, if not in fact for free.

Network slicing technology emerged to solve this problem. It uses the concept of cloud and virtualization to slice a network into many parts. All the slices share the same physical air interface and network equipment, but the QoS (Quality of Service) of each slice is different. Moreover, the slicing is dynamic and defined by software. Thus, you can create a certain slice for a task, cancel it when the task is over and then create a new one for a new task. Slicing technology enables customized network service and offers a good opportunity for telecommunications operators: they can exploit different slices to offer different kinds of services and are no longer restricted to smart phone based services.

NSR: Is 5G technology already mature?

Tong: Yes. There are no significant technical problems left. The main question now is on the business side.

TOWARDS AND BEYOND 5G

NSR: When did Huawei start 5G research?

Tong: Huawei started very early in 2009, when 4G LTE (Long Term Evolution) was still not fully commercialized. In that year, Huawei proposed a small project called Vision2020, which aimed to predict the shape of the wireless network in 2020. Many of the predictions made at that time turned out to be the same as in the recent 5G blueprint, including the network speed, latency and the application forms. Around the end of 2012, Huawei decided to invest 600 million dollars in 5G research and development—quite aside from our investment in actual products.

NSR: Did other major companies start at a similar time?

Tong: According to my knowledge, Huawei was probably the first company doing research in this field. Before 2012, many big companies were still publically claiming that 5G is impossible. We started early and firmly, and our major technical route has not been changed during these years. So at the early stage of defining 5G, Huawei played a significant role to lead the definition of speed, latency and connections.

NSR: Is there a future timeline for 5G commercialization?

Tong: It is said that 2020 will be the first year of 5G commercialization. But in fact we won't wait that long. In the second half of 2018, the 5G network equipment will be put into production and the network construction will begin. 5G smart phones will come out in the first half of 2019.

NSR: Will the cost of 5G be higher than before?

Tong: There are two kinds of cost. The cost for customers will not rise noticeably. iPhone X is already expensive, and the price of 5G phones won't exceed that level. For operators, the cost is in the network construction. They need to invest at the beginning and recover their costs in about three to five years. In the long run they are going to make a profit, and the price of data traffic will decrease.

NSR: How did China's Ministry of Industry and Information Technology (MIIT) promote the development of 5G?

Tong: MIIT organized the IMT-2020 (5G) Promotion Group in 2013. This group is among the earliest national 5G groups and has been proved to be successful. The Promotion Group brought major operators and vendors together to reach a consensus on 'what is 5G' and 'what is 5G technology'. The group also organizes tests of the technologies produced by its members. The second-stage test was carried out recently and achieved some of the world's best results. China is now a leading force of communications technology and industry. But in the time of 3G, we had to follow what was being done elsewhere.

NSR: What is beyond 5G? Will there be 6G?

Tong: Yes, there will be 6G. This is also a question I have been asked for many times. Both your and my imagination is limited; we cannot predict technological revolutions that could happen in 10 years' time. But when technological disruption and application disruption come together, 6G will definitely emerge.

NSR: As far as you know, has 6G R&D started at Huawei or other companies?

Tong: Well, I think there may be some basic research but we have not reached a point where we can say that 6G is coming. Several years of exploration and preparation are needed.

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PERSONAL CHOICE, COMPANY GROWTH AND INDUSTRY DEVELOPMENT

NSR: You joined Huawei in 2009, the year 5G R&D started in Huawei. So did you join Huawei for 5G?

Tong: This is a good question but I haven't thought about it. Maybe I should talk about my personal background. I got my bachelor degree in 1984 at Southeast University in China. Then I went to Canada for PhD. My PhD work was on signal processing and my doctoral thesis was a finalist of the Governor General's Awards. That was when 2G standardization was completed. When I got my PhD I was not clear about my future plan, so I accepted the invitation of Canada's Bell North Research Laboratory and became a postdoctoral researcher. During this period, some of my work was about speech recognition and neural network. At that time, I wasn't positive about the future development of neural networks and AI. So when I decided to head into industry, I didn't choose related jobs but accepted the offer of Nortel Networks, following my mentor's advice.

Nortel was a dominant digital switching network company at that time, and the wireless department was quite small. In a small department there were fewer restrictions and the young researchers could do anything they wanted. I still remember that in the company's annual exhibition I demonstrated how to download a website on a mobile phone using a refrigerator-size 3G prototype in the laboratory. The president came and saw it, and said: "What are you thinking about! Who will surf the internet with a phone!" In the wireless market Nortel was not the number one, so the only choice to become a leader in the field was through a technological revolution. I made a lot of technical contributions in the process of 3G and 4G standardizations. I introduced OFDM (Orthogonal Frequency Division Multiplexing), Turbo Code, Hybrid ARQ (Automatic Repeat-reQuest) and wireless Voice of IP technologies into standardization. In 2007 Nortel began to implement a Fellow system and I was the first Fellow. Later I became the leader of all the Nortel laboratories, inside and outside Canada. However, good times do not last long: Nortel went bankrupt in 2009. I was already a Nortel Fellow, so I figured that if I joined a sister company I would only attain a similar position—and that wasn't challenging. So I had only two choices: Google or Huawei. These two companies are different from Nortel. And I chose Huawei.

NSR: What are the differences between Huawei and Western companies?

Tong: There are differences. What's more, the Huawei of 2009 was different from Huawei nowadays. In my personal view, Huawei has several unique characteristics. The first is its desire to pursue technology excellence. This was unexpected to me before I joined. The second difference from Western companies is that Huawei is a customer-centric company, not a shareholder-driven company. You cannot really appreciate this if you're not an employee of Huawei. The third point is the strong capability for execution: once Huawei decides to do something, the entire company will concentrate on it with laser focus until it achieves the goal.

NSR: Was the Canadian R&D Institute of Huawei founded after your joining?

Tong: Yes, I joined Huawei together with a multidisciplinary team of about 200 leading experts and we founded the R&D Center in Canada. Huawei's performance on building overseas institutions is the best among all Chinese corporations. We have more than 20 centers in Europe and more than 10 in the USA and Canada. Many world-class talents are working in these centers and are helping Huawei to turn knowledge and technology into products and value.

NSR: How does Huawei decide where to set up an overseas institution?

Tong: It mainly depends on finding the right talent and research culture. Where we find it, that's where we build an institute.

NSR: What are the promoting research hotspots in the field of ICT?

Tong: Many technologies go through a period of overhype and then cool down, and probably only then re-emerge and begin to change our lives. That's the typical law for technology development. As an R&D researcher, you get success by persisting through the period of cooling until technology transfer finally starts to happen. AI has gone through this sequence. Huawei is also interested in AI, but personally I am still skeptical of it in the near future. It is true that it can be applied in many fields and offers efficiency and profits, but people's expectations exceed that promise.

NSR: Your undergraduate university, Southeast University, is strong in the field of communication.

Tong: I entered Southeast University and majored in radio technology in 1980. At that time, radio technology was an unpromising subject for students. However, Southeast University hosted China's best wireless communication lab at that time. The lab leader was China's first PhD supervisor in the field of wireless mobile communications. The first Chinese home-trained PhDs in this field, including Xiaohu You (IEEE Fellow, professor at Southeast University, the leading scientist behind China's 3G and 4G, with a PhD degree in 1988) and Zhengmao Li (executive vice president of China Mobile Communications Corporation, with a PhD degree in 1988) graduated in this lab.

NSR: What are your suggestions to young R&D researchers?

Tong: I've participated in recruitment at Huawei and learnt about the career choice standards of the young generation. Some are salary-guided, some care about the room for career development, and some are interest-driven. However, in my opinion, the top two determinants of the best young researchers are, first, whether he/she has a rough plan for the next 5 or 10 years, and second, they are usually 'stubborn' and able to stick to one subject for a long time. These principles are effective no matter which company you join, Google, Microsoft or Huawei.

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