Optical fiber expansion and 5G

Correlations and Synergies

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White Paper | Project group "Convergent networks as infrastructure for the Gigabit Society" | Focus Group "Moving into the Gigabit Society" | "Digital Networks and Mobility" platform

Contents

1 Introduction

In the course of the work on the IT summit 2016, the project group "Convergent networks as infrastructure for the Gigabit Society" has described and characterized suitable network infrastructures as the basis for the Gigabit Society.[1] The latter has been understood as an everyday reality that has changed in the course of digitalization in essential professional and personal environments with great potential for society and economy. In doing so, it was found that the Gigabit Society is characterized by the availability of high-performance networks in the area, which must meet heterogeneous functional requirements (such as data rate, latency or seamless connectivity). These heterogeneous network requirements are served by various network access technologies (fixed line network, mobile phone / wireless). In the process, each of the various access network technologies on different transmission media in the technology mix (copper twisted pair, coaxial cable, optical fiber, mobile) make important contributions to the implementation of the requirements of the Gigabit Society.

The strategy paper from 2016 made it clear that virtually all access network technologies in the fixed line network and mobile network are already based on differently extensive optical fiber expansion in the connection network. In order to be able to meet the future requirements (particularly high data rates, symmetry, latency and fail-safety) of the Gigabit Society, the project group has highlighted the expansion of optical fiber expansion towards customer locations (i. e. households, commercial establishments, mobile radio stations) as a central component for all network access technologies. In addition, the importance of a convergent orientation of the different access networks has been emphasized in order to be able to implement and use services efficiently in the Gigabit Society across platforms. Finally, it was shown that mobile connectivity is becoming increasingly more important.

Based on these findings, the project group presents in this document how the optical fiber expansion in the fixed line network favors the implementation of 5G and what are the complementary correlations that exist. In addition, the document establishes starting points for how synergies in optical fiber expansion can be utilized in optical fiber expansion. At the same time, it also mentions the challenges of a linked expansion.

1 "Converged networks as infrastructure for the Gigabit Society" Strategy Paper, IT summit 2016, "Digital Networks and Mobility" platform.

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Optical fiber expansion and 5G
Why do both belong together?

In order to be able to establish the correlations between the optical fiber expansion in the fixed line network and 5G, it is important to understand the requirements placed by 5G on the connection of the mobile radio stations and the driving forces leading to the expected cell concentration. To this end, the essential characteristics of a mobile network are illustrated below to begin with:

- A mobile network is built up of cells that overlap in the sense of the largely uninterrupted utilities. The size of the cells is influenced by the transmission power and the frequency-dependent propagation conditions, that is, the higher the frequency, the greater the attenuation and thus, potentially smaller the size of the cell.
- In terms of transmission power, you basically differentiate between macro cells and small cells. The former are usually provided by transmitting locations on roofs or towers and represent the currently dominant form of a mobile phone network. The small-cell base stations are usually located inside buildings (indoor utilities) or on "city furniture" (e. g. street lamps, bus stops etc.) or at lower heights on buildings.
- The data rate that can be achieved for a single user depends on the mobile technology, the frequency bandwidth used, the user's distance from the transmitting antenna and the number of simultaneous users in a given mobile phone cell ("shared medium"), as well as the minimization of cross-cell interferences.

Hence, you have the following options in order to increase the data rate for the mobile phone users:

- Use of the latest mobile technology with higher spectral efficiency
- Commissioning of more spectrum at a transmitting location (e. g. for 4G or LTE Advanced with a multiple of 20 MHz)
- Reducing the number of users per cell (location concentration)

With progressing 5G standardization, the requirements for 5G become increasingly clearer. According to the current proposal of the International Telecommunications Union (ITU), the 5G technology is meant to be characterized by the following properties:[2]

- Theoretical peak data rates up to 20/10 Gbps (downstream / upstream) under ideal conditions
- 100/50 Mbps (downstream / upstream) throughput rates for any user at any time in central city locations
- Short latency times of 1 ms for services with extreme delay requirements or 4 ms for the mobile broadband application case
- Traffic densities of 10 Mbps/m² for hotspots within buildings

It is clear to the industry that these requirements cannot be met everywhere and cannot be met simultaneously for each usage scenario. On the contrary, it is assumed that certain focuses of use will be set. This applies, for example, to industrial and manufacturing plants, to the subject of networked driving and to extended mobile broadband applications (e. g. mobile video consumption).

2 ITU 5G performance decision draft: https://www.itu.int/md/R15-SG05-C-0040/en, Adoption of the final performance requirements in November 2017

As an illustrative example of these requirements, the application case may be termed "connected driving". On the one hand, connected driving uses a reliable connection with guaranteed and moderate latency. On the other hand, the foreseeable more intense use of mobile broadband services by the vehicle occupants requires a high network capacity along the roads.

Regardless of the final standardization, it can be said that the 5G performance marks (data rates, latencies, traffic density) will be somewhat beyond the current possibilities of the 4G/4.5G mobile technologies. They place substantially enhanced requirements both on the connection bandwidths of the mobile radio stations and on the future locations, which will mainly extend to urban areas and industrial facilities as well as along the traffic routes.

5G leads to capacity increase of the mobile network and requires additional spectrum (the so-called 5G pioneer bands[3]). New spectrum in the upper frequency range above 6 GHz (e. g. 26 GHz) has different propagation characteristics than the previously used frequencies. In particular, the requirements on the line of sight between transmitter and receiver increase, which limits the range. In addition, there are approval restrictions, especially in urban locations, for example with respect to the bearing loads or wind loads or also with respect to electromagnetic compatibility. For these reasons, the new spectrum will be used primarily at new locations, which is equivalent to a location concentration. This is especially true for the 5G pioneer band at 3.5 GHz, which is also likely to be offered for network capacity augmentation at locations where the corresponding demand exists, for example, along main traffic routes[4].

In addition, essentially higher carrier bandwidths of at least 100 MHz (for frequencies below 6 GHz) or up to 1 GHz (for frequencies above 6 GHz) are expected for 5G. This is accompanied by a significant increase in the data rates to be discharged per location.

In summary, it can be said that 5G allows a significant increase in the data rate that must be discharged per transmitter location and also requires the commissioning of numerous new mobile radio stations.

In view of the requirements of 5G expected in the long run regarding data rate, latency and fail-safety, the optical fiber is basically the most future-proof and scalable medium. In addition, it is operationally cost-effective in the long term because there are no longer active network elements between the control center and the mobile radio station. Today, mobile radio stations are already connected with optical fiber, but also with directional radio and copper cables. In the future, alternative connections of mobile radio stations for 5G will remain relevant for the sake of cost, provided that they meet the requirements of the respective 5G use case scenario at the relevant mobile radio station. The widespread HFC networks may also make an important contribution through the upcoming deployment of the powerful DOCSIS 3.1 technology. Finally, the data traffic collected via alternative connections must also be transferred to a fiber optic network (at the directional radio location, serving area interface, fiber node). From a technical point of view, a pure fiber optic connection of the mobile radio stations is the most efficient choice in the long run.

Even for the sake of network management, the optical fiber connection of 5G locations is optimal. Due to the cellular nature of mobile phone networks, there are always interferences with neighboring cells at the cell edge, which significantly impairs performance. This problem can be reduced with the introduction of 5G. However, this requires the fast and low-latency coordination of all neighboring transmitting and receiving stations. For this reason, the optical fiber is the first choice from the technical point of view, as alternative backhaul technologies may lead to necessary compromises in the achievable coordination performance.

3 See 5G focus group, "5G – Spectrum Demand and Use", IT summit 2016
4 See 5G focus group, "Spectrum Use Paper", 2017 Digital Summit

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Synergies between the fixed line network and mobile network whilst developing the fiber optic infrastructure in Germany

After the technological correlation between optical fiber expansion and 5G has been worked out, synergies are discussed below. It is important to note that the optical fiber infrastructure in Germany is constantly undergoing advanced development. The driving force is primarily the broadband expansion in the fixed line network, in which all network operators in Germany are rolling out optical fiber nationwide in order to connect residential and commercial regions. In the course of the network evolution in the former telephone- (based on copper cables) and cable TV networks (based on coaxial cable), the fiber optic network is expanded over a wide area up to the serving area interface ("Fiber to the cabinet") or up to the fiber nodes ("Hybrid fiber coax"/HFC). Coverage of the HFC networks encompasses about 70 % of German households.[5] Over the next few years, strengthening the copper network will tap into over 90% of the households with optical fibers up to the serving area interface at the roadside. In the expansion area, fiber optic connection networks that reach up to the building (FTTB and FTTH) will generate the most extensive fiber optic infrastructure that covers all developed routes. At present, FTTB/H networks are available for about 7 % of the German households.[6]
The expansion of these fiber optic infrastructures is essentially governed by the market. In uneconomical regions, the funded expansion contributes to the spread of fiber optic infrastructure.

The expansion of the fixed line fiber optic infrastructure towards the customer locations creates synergy potential for a future fiber optic connection of (small cell) mobile radio stations. At certain points, optical fibers can be connected to all fixed line network architectures. These are, for example, multifunctional housings (FTTC, HFC), network distributors (FTTH/B) and optical fiber sockets in shafts (all topologies). With FTTH/B topologies, there is still an additional connection option in the building itself. A continuous connection between the "Fiber point of presence" (for example at the main distributor) and the mobile radio stations can be generated at all these points. If additional civil engineering is required, the connection via an empty duct (micro tubes) leads to a future-proof route fortification for subsequent FTTH/B expansion.

Due to the advancing supply of fiber optic cables in the fixed line area, the fiber optic infrastructure in these areas of expansion is no longer the only limiting factor, but the locations themselves (e. g. expansion/usage permits and requirements). However, the activities of broadband expansion in the fixed line network are focused on populated regions. Hence, there are new challenges, for example, in areas for agricultural and forestry use, or along mobility routes such as district, state and federal highways, which are, indeed, of minor importance for mass market services, but also in the focus of the Industry 4.0 or IoT

5 ANGA Registered Association of German Cable Network Operators: The German broadband cable 2016
http://www.anga.de/media/file/937.Anga_Factsheets-BB-online.pdf
6 BMVI, "Current Broadband Availability in Germany (as of end 2016)", page 5
https://www.bmvi.de/SharedDocs/DE/Publikationen/DG/breitbandverfuegbarkeit-ende-2016.pdf?__blob=publicationFile

As shown in the strategy paper of 2016, future applications place very heterogeneous demands on the networks of the Gigabit Society (cf. chapter 2, strategy paper of 2016). Services with very high capacity demand require the construction of new locations with fiber optic connection. For other applications in the field of IoT (focus range, energy-efficient terminal devices) or vehicle control (low latency, high speed of movement, low to moderate data rates), in contrast, macro cells are well suited in many scenarios.

The need to build up small cells and connect them to the fiber optic network also depends directly on the services and their requirements. From the current perspective, these cells are primarily used to increase capacity, and not necessarily to minimize latency. The more the number of small cells that are needed, the more expensive is the network expansion and the more challenging is the development of viable business cases. Important factors influencing the business case are the location acquisition, the implementation of the network connection and the expected turnover.

Given that bandwidth-intensive services are also meant to be used in regions with areas for agricultural and forestry use or along mobility routes, such as district, state and federal highways, it results in no synergy potential or very weak synergy potentials with the optical fiber expansion of all the actors in the fixed line network for any necessary comprehensive cell concentration and its fiber optic connection.

For the 5G network expansion, it is therefore necessary to develop viable business models for different use cases also as part of commercial cooperations between network operators as well as with the industry and other market participants. For example, a flat small-cell structure for maximum data rates along the state or district highways poses a greater challenge than an IoT scenario, which is facilitated by the macro cells of the region. In the process, the infrastructure will develop along the demand for mobile applications and the business models will emerge according to the criteria of viability.

4 Conclusion

Already last year, the project group has worked out that practically all access network technologies are based on differently extensive fiber optic expansion. Following up on this, systematic correlations between the fiber optic expansion in the fixed line network and the implementation of 5G are established in this document, since 5G is dependent on high-performance connections with optical fiber as far as possible.

- In the future, numerous new mobile radio stations will also have to be connected nationwide with optical fiber.
- The broad expansion of fixed line fiber optic infrastructure by all network operators in Germany creates synergy potential for a future connection of (small cell) mobile radio stations with fiber optic. Synergies can be achieved by further connection of optical fibers at certain points of all fixed line network architectures, as the investment-intensive civil engineering expenses for 5G will be reduced considerably. As a result, the fixed line network expansion also facilitates the implementation of 5G.
- New challenges remain, for example, on areas with agricultural and forestry use or along mobility routes such as district, state and federal highways, since the activities of broadband expansion in the fixed line network focus on populated areas.
- The identified synergies and correlations between the optical fiber expansion in the fixed line network and 5G can result in additional market potential for fixed line network operators in order to participate in the 5G value-added chain. Hence, the convergence of fixed line and mobile networks enables cooperation between the operators of the respective infrastructures.
- In addition, it is necessary to develop viable business models for different use cases between network operators among one another, as well as with the industry and other market participants.

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