

Challenges and opportunities in next generation personal small cell networks

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Abstract- In this paper, we envisage 5G small cell architecture for personal use and enumerate upcoming challenges to be solved. Based on previous studies related to our view, we discuss way forward to realize the 5G personal small cell networks.

Keywords- Small cell, 5G, pico cells, millimeter wave, wireless beam forming

1 Introduction

Fast growing mobile traffic associated with tremendous number of smart phones, tablets and gadgets for Internet of everything enforces network operators deploying next generation networks which are capable of embracing upcoming large data demands like UHD, 3D, graphic data for virtual or augmented reality, and so on.

From this, 5G wireless communication and network are recently started to discuss in standard groups and forums. 5G organizations such as 5GPPP and 5G forum [1,2] are releasing their own view of the 5G communication and network in terms of network architecture, candidate technologies and services. Several 5G projects such as METIS and 5G NOW launched by EU are already publishing their research results about the technical issues for the 5G communication. Also, some telecommunication manufacturers have announced their preliminary empirical results about the 5G wireless technologies including millimeter waves.

The millimeter wave technologies attract much attention from the wireless communication domain since spectrum scarcity in current cellular communication is serious hurdle to increase cell capacity. So, cellular operators are seeking techniques to minimize deployment costs with smaller and denser cells for higher capacity. Although the channel characteristic in the 20-40 GHz is not friendly to outdoor communication due to fading from moving objects, blocking by buildings, and huge path loss, it has advantages in antenna related technologies such as massive and pencil beamforming, multi-user diversity, together with reduced antenna array size.

The small cells technology is one of the 5G key technologies to improve network capacity. Major benefits from the small cells are increased data rates, coverage and service quality for users, which leads to reduce congestion in overloaded macro cells by offloading. However, there still exist many challenges to deploy such small cell networks. Deployment of conventional femto-size small cells requires effort and cost proportionally to the size of service area. In contrast, in the 5G wireless communications, ultra-small cells can be created using the pencil beams of the millimeter-wave, and they can be also created and removed dynamically.

The ultra-small cells can be assigned for each user, called as a personal cell. In near future, as people carry many IoT devices for vehicles, medical treatment, and various personalized services, the personal cells will be popular. The personal small cells have many technical challenges from a physical to an application layer such as cell establishment, seamless handover, group mobility and session management. Also, power and resource scheduling mechanisms for the personal cells need to be considered.

In this paper, we envisage 5G small cell architecture for personal use and enumerate upcoming challenges to be solved. Based on previous studies related to our view, we discuss a way forward to realize the 5G personal small cell networks.

2 5G Personal small cell networks (PSN)

Connectivity is essential for IoT devices because information they collect need to be delivered to a main computing system like a cloud computer that analyzes it and performs or orders something to other devices. Ad hoc networks within the personal area cannot provide tactile response due to sleep cycle and multi-hop communication.

Figure 1 illustrates a cellular network model for the personal small cells. Base stations (BSs) are located on the roof top or side wall of the buildings and the roadside control their beams to form a small cell for each person. According to [4], the pencil beam can create a small cell with 3~4 m that

could be isolated from other users typically. The cell size depends on used frequency spectrum; it will be decreased if a higher frequency is chosen for the system band.

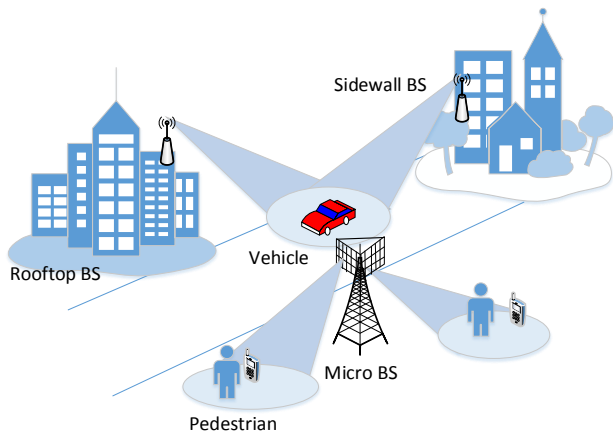


Fig 1. Network architecture of personal small cell

For this 5G personal small cell networks (PSN), following challenges and issues can be presence.

- i) Create a small cell for each person which does not interfere with other neighbor cells.
- ii) Support seamless handover for various mobility types from pedestrian's walking speed to vehicle's moving, more than 60 Km/h in urban road.
- iii) Support group session mobility for personal IoT devices with QoS.
- iv) Operate small cells based on radio resource and energy efficiency.

3 Technologies for 5G PSN

In this section, we look into details of challenges and discuss candidate technologies.

3.1. Small cells created by millimeter wave beamforming

MIMO has become an essential element of wireless communication to accommodate more information data. By using multiple antennas a significant performance improvement can be achieved in terms of reliability, spectral efficiency, and energy efficiency. In massive MIMO systems, the enormous number of antenna elements (typically tens or even hundreds) can be possessed by one device [3]. This can be reinforced by millimeter wave such that a 100-element 60GHz array easily fits in no more than a square inch [4]. This is hundreds of times smaller than arrays with the same number of elements for frequencies at or below 5GHz. Furthermore, in massive MIMO systems, the effects of noise and fast fading vanish, and intra cell interference can be mitigated using simple linear precoding and detection methods. Also, characteristics of the millimeter wave such as high path loss and directional link can reduce inter cell interference.

Outdoor small cells are preliminarily explored by [4] in 60 GHz frequency spectrum. The study demonstrated feasibility of outdoor pico- or femto-cells using 60GHz in a campus testbed. Empirical results indicate that the cell range is enough for pico-cell and interference and blocking from

moving pedestrians are negligible. Reflection or "picoclouds" scheme like coordinated multi-point (CoMP) can be used for blockage from static or nomadic obstacles. Pencil beam from increased number of antenna array can reduce reciprocal interference among neighbor pico-cells. Although some challenges including user tracking and spatial diversity need to be further studied, a single user per single cell is proven as a feasible idea in 5G wireless networks.

3.2. Coordinated Multipoint (CoMP) transmission

CoMP is one of key technologies to improve cell edge user data rate and spectral efficiency. The CoMP is mainly regarded as two methods, joint transmission (JT) and dynamic cell selection (DCS). Coordinated scheduling and beam forming is another crucial part of the CoMP. For the 5G PSN, cooperation among millimeter-wave based BSs will be accelerated for line-of-sight (LOS) transmission and soft handover. Previous CoMP scenarios of LTE advanced have limitations for realization due to non-ideal backhaul that delivers control signals among BSs or remote radio headers (RRHs). Fortunately, 5G wireless networks can remove such backhaul delay by relocating most parts of the BS function to a cloud except time-critical functions such modulation as a concept of RAN virtualization, i.e., cloud RAN (C-RAN) [5].

Basically, the personal small cell can be formed by multiple transmission points (TPs) in the C-RAN architecture. Such a cell cluster for each user impacts on user equipment (UE) performance [6]. Thus, based on the CQI/RI/PMI information from UEs within a cluster, the C-RAN can allocate radio resources efficiently to improve network performance and personal cell throughput using scheduling algorithms, such as Space-Division Multiple Access (SDMA) algorithm [7].

The CoMP DCS is useful for 5G PSN such as adaptive LOS acquisition and low complexity of implementation. However, spectrum is not efficiently used since the other eNB should be muted in case of DCS in two BSs. We can consider a coordinated beamforming technique solving this problem [5].

CoMP can also improve the handover performance especially for fast moving users, e.g., by vehicles and trains in the PSN. A set of BSs can form a virtual cell with a logical identifier, which does not lead to handovers in the C-RAN. Also, it can support soft handover using the inter BS CoMP, in which TPs of a target BS become involved in the CoMP set before starting handover [8].

3.3 Group session mobility

Group mobility for personal IoT devices has been previously considered for trains or vehicles. A mobile relay, which works similar to a static relay BS, is placed within a group to relay data from subordinated devices to a macro base station or vice versa. Technically, the mobile relay plays a role of a normal BS to the clients and it acts as a mobile client to the macro BS at the same time [9]. The mobile femto-cell (MFemtoCell) is newly proposed as a potential candidate technology in 5G networks [10]. It combines the above mentioned mobile relay concept with the femto-cell technology. The mobile femto-cell is a small cell that can move around and change dynamically its connection to a

cellular core network. Here, multiple sessions within a group now assume to be handled according to the policy of the conventional macro base stations. However, in personal femto-cell, a new policy has to be defined, for example, application specific or IoT device energy consumption specific rules.

3.4 Energy saving

The design of 5G PSN should also take into account saving energy as dense small cells can consume tremendous electric power. An intuitive idea for reducing energy is to minimize duty operation (active period). The cluster based energy efficient Available Interval (AI) scheduling for mobile WiMAX (802.16m) is proposed in [11]. In this scheduling, a leader small cell BS is first elected and controls AI of member BSs within the C-RAN when a mobile comes in. From this, unnecessary AI is reduced which leads to decrease co-layer interference among those small cells. Femto BS switches off all RF functions during the idle mode, which reduces power consumption by 37% [12]. Thus, in the PSN, the personal cells can be formed by duty cycle in order to overhear uplink transmission signal from UEs. If it detects UEs, then it turns on the RF functions and enables UE to access to the personal cell. Otherwise, always-on macro cell can hear the voice from the UE anytime and enforce to turn on and off those small cells dynamically. In scheme [13], intermediate BSs that can be covered by neighbor base stations can be switched off adaptively. In the PSN, we can also think about zooming in and out cell size according to power efficiency.

4 Conclusion

In this paper, we have pondered 5G personal small cell networks (PSN) architecture. We have defined four challenging issues including creation of a small cell per person, seamless handover, group session mobility, and energy efficiency. Recent key technologies to overcome the issues have been investigated and discussed future works to realize the 5G PSN.

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