USER-CENTRIC ULTRA-DENSE NETWORKS FOR 5G: CHALLENGES, METHODOLOGIES, AND DIRECTIONS

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ABSTRACT

Ultra-dense networking (UDN) is considered as a promising technology for 5G. In this article, we define user-centric UDN (UUDN) by introducing the philosophy of the network serving user and the "de-cellular" method. Based on the analysis of challenges and requirements of UUDN, a new architecture is presented that breaks through the traditional cellular architecture of the network controlling user. Dynamic AP grouping is proposed as the core function of UUDN, through which a user could enjoy satisfactory and secure service following her movement. Furthermore, we provide methods for mobility management, resource management, interference management, and security issues. We point out that these functions should be co-designed and jointly optimized in order to improve the system throughput with higher resource utilization, better user experience, and increased energy efficiency. Finally, future works in UUDN are discussed.

INTRODUCTION

Mobile Internet and mobile apps, enabling us to connect with the world anytime and anywhere, are changing people's daily lives. Popular mobile Internet services include online multimedia streaming, mobile social networking, interactive gaming, and so on. Those lead to the explosive mobile traffic growth in recent years. Based on statistics [1], the global mobile traffic volume in 2013 had increased 30 times compared to that in 2008. In the future, more and more devices will be connected by mobile systems, and many new services such as ultra-high definition video, 3D video, virtual reality, and augmented reality will be supported through smart mobile devices. This will lead to faster increases in mobile traffic, especially in dense user areas. Telecommunication is now evolving to a new generation of mobile system, that is, the fifth generation (5G), toward 2020 and beyond [2]. One of the key requirements is very high traffic density in crowded city and hotspot areas. In some typical scenarios, the area throughput requirement may reach as high as 20Tb/s/km^2, which is equal to 20 Mb/s/m^2 [3]. Area spectrum efficiency becomes one of the key metrics to evaluate future mobile systems for very dense traffic demands [4], and then impacts system capacity.

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There are three methods of enhancing system capacity:

- Increasing the spectrum efficiency of the air interface (bits per second per Hertz) by better modulation and channel coding
- Adding more spectrum bandwidth
- Spectrum reuse by reducing the cell size

In [5], it is observed that by 2008, the wireless communication capacity had increased 1 million times from 1957. Among these gains, 25× improvements came from wider spectrum, and 25× improvements were contributed by advanced air interface design, and 1600× huge improvements were due to reduced cell sizes and transmit distance. From the viewpoint of evolving techniques, the potential gains derived from the advance of wireless modulation are approaching the floor. Therefore, we can conclude that the increasing density of access points (APs) with smaller coverage is the most efficient way to improve system capacity, especially in hotspots. China promoted Long Term Evolution (LTE)-Hi [6] to increase the system throughput for indoor and hotspot areas. Small cell enhancement is one of the most important features of Third Generation Partnership Project (3GPP) Release 12 [7]. In International Telecommunication Union — Radiocommunication Standardization Sector (ITU-R) Report M.2320 [8], ultra dense networking (UDN) is promoted as one of the technology trends to meet the high throughput requirement of 5G. And METIS [9] considers UDN as one of the most important topics toward the mobile system for 2020 and beyond.

In this article, we identify UDN toward 5G with the following characteristics:

- Very high density of APs for plenty of mobile access opportunities
- Various kinds of APs for flexible network connection choices
- Heterogeneous networks with different coverage ranges and multiple radio access technologies (RATs)

Ever since Bell Labs proposed the concept of a cellular network in the 1970s, this architecture has been adopted in successive generations of mobile networks. For the architecture evolution path, [10] points out that the macro-local coexistence and coordination in 5G and on will replace the macrocellular-dominated architecture of 1G to 4G. UDN is a local-area solution

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for 5G. In this article, we propose user-centric UDN (UUDN), which breaks through the traditional network- centric cellular architecture. We present challenges for UUDN, and then we introduce a new architecture of UUDN, and also propose the core function and methodologies in mobility management, resource management, interference management, and security. Conclusions and future work directions are given at the end of this article.

Concept and Challenges of UUDN

What Is UUDN?

UDN aims to provide very high data rate to each user at indoor and hotspot areas, including office, dense residential, stadium, and open-air-gathering environments, and so on [8]. A traditional cellular system usually provides seamless coverage for a large area. Distinct characteristics of UDN and the traditional cellular network are summarized in Table 1.

The main difference between UDN and the traditional cellular network is the density of APs or base stations (BSs). There are perhaps thousands of APs in 1 km^2 in UDN, compared to at most three to five BSs in 1 km^2 in the traditional cellular network. Correspondingly, only one or a very limited number of users is connected to one AP in UDN, whereas hundreds or even thousands of active users are supported by one BS.

Another key point is the various types of APs in UDN. Besides small cell stations, relay stations, and distributed remote radio heads (RRHs), user equipment (UE) itself can also act as APs in UDN. In a traditional cellular network, a macro BS is the main access unit for connection.

Besides the above characteristics, heterogeneous topologies, irregular coverage, flexible backhaul, wide range spectrum band, lower mobility, and very high data rate and traffic volume are also obvious differences between UDN and traditional cellular networks.

Based on the above, we conclude that UDN is quite different from the traditional cellular deployment. In this article, *we define UUDN by introducing the philosophy of the network serving user and the "de-cellular" method. UUDN is a wireless network in which the AP density is comparable to the user density. This network will organize a dynamic AP group (APG) to serve each user seamlessly without the user's involvement.* UUDN lets a user feel like a network is always following it. Thus, the network shall intelligently recognize the user's wireless communication environments, and then flexibly organize the required APG and resource to serve the user.

There are four main features of UUDN.

An Intelligent Network Knows the User: The network will be more intelligent and can automatically detect the terminal's capability, user requirements, and its radio environment, as well as construct knowledge information for each user.

A Moving Network Follows the User: While a user is moving, its APG will be adjusted dynamically to support its movement, which is quite different from the traditional mobility management and handover process.

	UDN	Traditional cellular network
Deployment scenarios	Indoor, hotspot	Wide coverage
Access point density	Comparable to the user density	Much lower than user density
Access point types	Small cell, pico femto, UE relay, relay	Macro/micro base station (BS)
Typical coverage	Around 10 m	Several hundred meters and more
Coverage characteristics	Heterogeneous, irregular	Single layer, regular cell
User density	High	Low/medium
Backhaul	Ideal/non-ideal, wired/ wireless	Ideal, wired
User mobility	Low mobility	High mobility
Data rate requirement	High	Low/medium
Spectrum bands	Higher, wider	Lower, limited

Table 1. Comparison between UDN and the traditional cellular network.

A Dynamic Network Serves the User: An APG's members will be adjusted adaptively to match a user's service requirement. They can transmit a data stream jointly and cooperatively to enhance the spectrum efficiency and user experience.

A Secure Network Grants the User a Guarantee: The network will provide security guarantees through the AP's authentication when an AP joins the APG, and through UE-network authentication. The result of the authentication can thus be smoothly perceived or inherited between the members within the APG.

Challenges of UUDN

Challenges of Network Architecture: A typical 3GPP architecture for a home evolved Node B (HeNB) under the 4G LTE/System Architecture Evolution (SAE) framework is shown in Fig. 1 [11, 12].

In this architecture, the network side mainly includes five entities: the HeNB, local gateway (L-GW), mobility management entity (MME), serving gateway (SGW), and packet data network Gateway (PDN GW). The function of each entity can be found in [12].The function of the HeNB is almost the same as a traditional macro BS except for smaller coverage. The user's control plane and data plane are managed by the core network (CN).

For UUDN, AP density and area throughput will be much higher than 4G small cells. Its network will offer smart measuring of the user's radio environment and serve the user dynamically. In a typical scenario, various kinds of APs will be supported with their flexible backhaul. To realize those features of UUDN, challenges faced by the traditional network architecture,

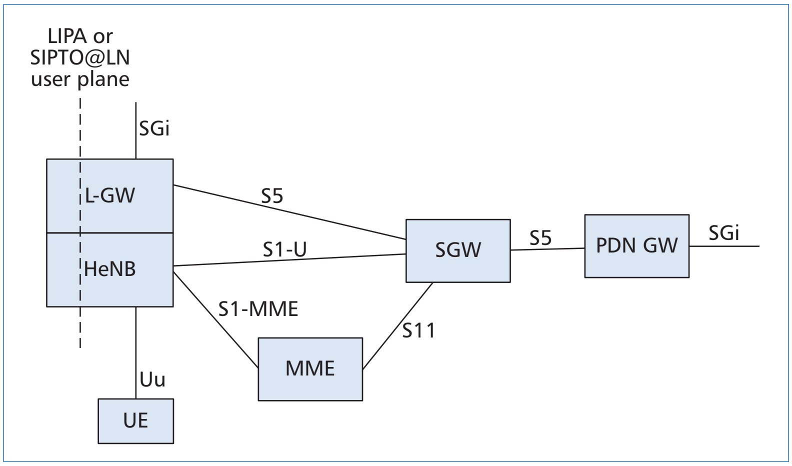


Figure 1. 4G LTE/SAE network architecture.

such as the one in Fig. 1, are:
- Many functions such as service control and mobility control are centralized in the CN (e.g., MME and PDN-GW/SGW). It is not efficient for UDN with very high traffic throughput and very dense APs deployment. This will lead to signaling overhead and longer data transmission latency between AP and CN.
- The tight coupling of the user plane and control plane in the air interface under high AP density scenarios will result in difficulties for heterogeneous networking.
- The traditional cellular structure with an HeNB has problems supporting APG, advanced interference management, and resource management for UUDN. The higher-layer procedure, radio resource management, and mobility management functions may not be easily distributed on each AP independently.
- The data transmission function of the L-GW cannot support user-centric services. More functions are needed to be collected and supported in the L-GW.

Therefore, the new network architecture of UUDN should support very high density AP deployment and flexible networking. In the new architecture, a localized service center should measure a user's radio environment, and provide better joint processing and quality of service (QoS) control. A mobility anchor close to users is needed to provide dynamic AP grouping. Meanwhile, the CN can be simplified.

Challenges of Mobility Management: The mobility management methods in a traditional cellular system cannot be applied to UUDN due to the following challenges:
- Location areas are statically configured in a traditional network. These areas are irrelevant to any user. The boundary of a location area in the cellular network becomes unclear in UUDN. Thus, the location management mode will be changed from static AP planning to dynamic AP cooperation.
- Handover control becomes difficult because of the irregular coverage and complex AP neighborhood relationships. Moreover, the different types of APs will result in complicated handover signaling processes. Therefore, the handover control of UUDN needs to be redesigned.
- The UUDN will follow a user's behavior (e.g., movement and on-demand services) to offer user-centric services in a more complicated wireless environment. Thus, the mobility management should be jointly optimized with resource management and interference coordination.

Therefore, the mobility management in UUDN may provide an amorphous, dynamic, and virtual location area, which consists of an APG and follows the user's movement. Hence, new handover methods should be designed.

Challenges of Resource Management: The resource management in UUDN is much different compared to that in traditional cellular networks. The consideration of resource allocation should be based on users and corresponding APGs, instead of on cells or APs. Furthermore, there will be various applications and increasing demands asking for more bandwidth and having different QoS requirements. Such a complicated communication environment challenges the resource management of UUDN:
- The resource allocation should be adjusted according to the member change of APG, without impacting ongoing and newly arriving traffic.
- Due to the rapid increase of AP density from the user's perspective, access opportunities, bandwidth, and other resources increase greatly. From the network side, the available resources cannot match the user's requirements. Under this situation, system throughput can be enhanced by multiplexing. Resource management becomes complex and needs to be flexible.
- The APG, not only a single AP, provides the services to users. How to assign the resources and balance the load among APs are important issues to satisfy users, especially in high-speed movement.
- The cooperation within APGs and among users (e.g., relay and multipoint transmission) may give another opportunity to improve system performance and resource utility.

We may foresee that the resource management in UUDN should be redesigned to meet the challenges brought by high AP density. The resource allocation needs to follow the APG change, cooperation, and load balance requirements flexibly.

Challenges of Interference Management: Interference management may directly impact system performance [14]. Along with resource multiplexing for more access opportunities, interference increases as well and becomes more complex in UUDN. We face the following problems:
- The ultra-dense environment results in more interference sources. For example, in crowded subway trains, lots of terminals and APs exist; therefore, signals may have more reflecting and scattering paths. The interference model becomes more complex.
- Decreased interference and increased resource utility are in contradiction. We need to find the proper trade-off.
- The traditional parameters to measure and evaluate the impact of interference, such as

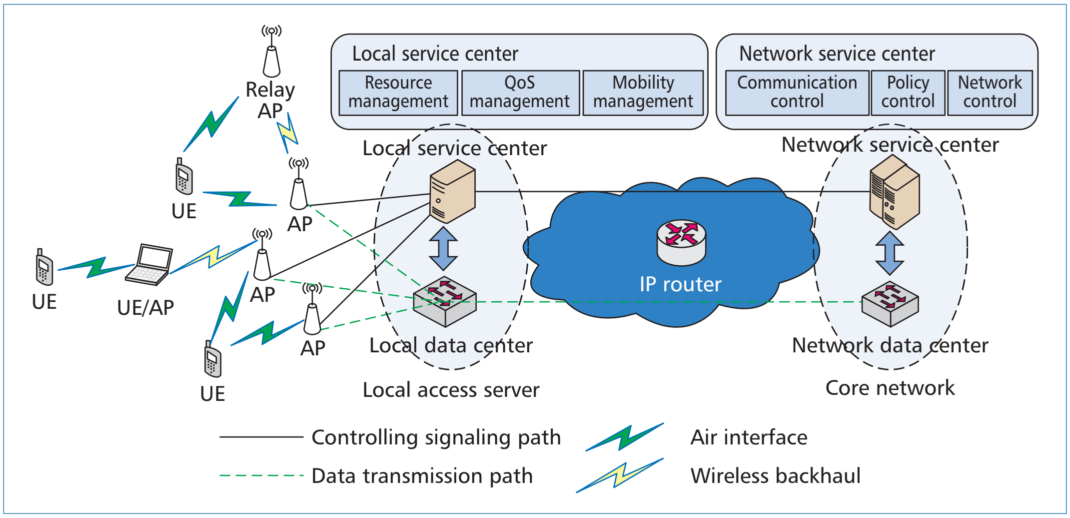


Figure 2. Network architecture of UUDN.

The resource management in UUDN is much different compared to that in traditional cellular networks. The considerations of resource allocation should be based on users and corresponding APGs, instead of based on cells or APs.

interference temperature and interference threshold, may not expose the overall interference measure and performance control of the networks. More suitable parameters should be discussed to give a better indication between interference managing results and throughput, associated with energy efficiency and other system-level parameters.

Therefore, we should set up new interference models, analyze the typical wireless transmission scenario, and then propose a better interference control approach for UUDN.

Architecture and Methodology of UUDN

De-Cellular Architecture and Functional Entities of UUDN

The philosophy of the UUDN will change from a network controlling user to a network serving user. We also introduce three kinds of decoupling: the decoupling of the user plane and control plane from radio access aspects; the decoupling of control and transmission from network aspects; and the decoupling of local service and network service.

Based on this philosophy, the UUDN architecture adopts the de-cellular method depicted in Fig. 2. In this architecture, there are no more "cells" logically and physically from the user's perspective. Very dense APs in one area will be organized intelligently to follow the user's movement and provide data transmission on demand.

Four functional entities are introduced to provide user-centric services (Table 2). At the radio side, the local service center (LSC) and local data center (LDC) are introduced to provide the logical decoupling of the control plane and user plane. All kinds of APs are connected to the LSC and LDC by various backhaul (ideal/non-ideal, wired/wireless). At the network side, the network service center (NSC) and network data center (NDC) are introduced to provide the control and transmit functions. The LSC and LDC can be integrated into one local access server as a physical entity, and the NSC and NDC may also be integrated into one CN entity.

	User plane	Control plane
Access network	LDC	LSC
Core network	NDC	NSC

Table 2. Function entities of UUDN.

The functions and interfaces of each entity are as follows.

- The AP is the radio access channel for UE including the data plane and the control plane. A UUDN AP can be built with RF, PHY, medium access control (MAC), and IP layer functions or combinations of them based on the backhaul capacity. If the AP has only RF, the PHY to IP layers will be centralized into LDC. With this architecture, LDC can provide joint processes in the PHY layer. Advanced signal processing can thus be used to avoid inter-AP interference in UUDN. In order to provide joint radio resource management and radio link management, the control plane of each user shall be centralized in the LSC.
- The LSC is the control service center to organize an APG to serve one user. It will have the new functions of user-centric radio resource management, multi-RAT coordination, effective QoS control, user-centric mobility management, and local radio link control.
- The LDC provides the user plane in UUDN. It will provide the user plane functions including higher layer processing and dynamic AP channel processing. It also has the functions of multi-AP coordination-based and multi-radio-bearer convergence for users.
- The NSC provides the function of user policy control; authentication, authorization, and accounting (AAA); high-level mobility (roaming, inter NSC handover); and so on.
- The NDC serves as the data gateway for transmission.

In the new architecture, the LSC and LDC are very close to the location of APs, so it is easy to provide user-centric services functions, advanced resource management, and interference management. It is more flexible for UUDN deployment

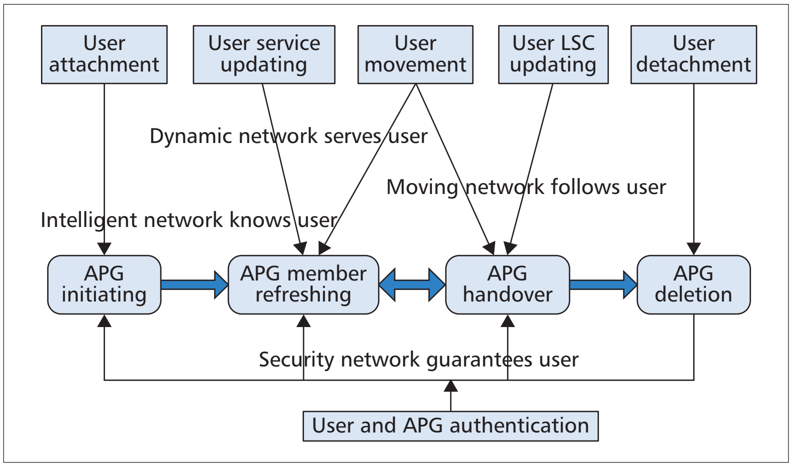


Figure 3. The main processes of DAPGing.

with the decoupling of the user plane and control plane, and decentralizing the CN functions to the LSC and LDC. Also, signaling overhead and backhauling overhead can be greatly reduced for UUDN scenarios.

For heterogeneous network, UUDN will coexist with traditional cellular networks. There are two possible methods of cooperation:

- Macro cellular BS act as the function of control plane, and UUDN act as the data plane for a user.
- The LSC and LDC entities are deployed as functions of Macro cellular BS. UUDN and Macro cellular system can thus have tighter couple. For example, they can jointly provide dual-connections in MAC layer to one user.

Dynamic APs Grouping Method Core Function of UUDN

In UUDN, we introduce dynamic AP grouping (DAPGing) based on one idea proposed for a mobility-driven network [11]; that is, user mobility is one key driving factor for future networking. With this method, every registered user in UUDN has a unique dynamic APG with a unique APG-ID. APG context will be stored in an LSC, and most DAPGing processes will be executed by that LSC. Some high-level processes such as authentication and handover are managed by an NSC.

The main processes of DAPGing include APG initiating, APG member refreshing, APG handover, and APG deletion, as shown in Fig. 3.

APG Initiating: A unique APG is created by the NSC and maintained by the LSC when a user is attached to the network based on the intelligent sensing of the user's radio environment. The APG always follows the user to provide user-centric services until the user is detached from the network.

APG Member Refreshing: After the APG is established, the APG member will be updated dynamically according to the user's movement and radio environment. When the user moves, members of the APG may change accordingly without the user's involvement. When the user is stationary, members of the APG may also be adjusted to meet the changes of the radio environment. The AP on/off will also lead to APG member refreshing.

APG Handover: When a user moves out of the LSC, the APG will be handed over from the LSC to another belonging to a different NSC.

APG Deletion: An APG will be deleted when a user detaches from the UUDN.

DAPGing is related to mobility management, resource management, and interference management. Meanwhile, the security impact of DAPGing needs to be considered.

Mobility Management of UUDN

In a traditional cellular network, users are handed over from one cell to another. In our de-cellular UUDN structure, the network will follow a user's movement. DAPGing makes mobility management functionality different. The following scenarios are shown in Table 3:

- For intra-LSC or inter-LSC mobility, only APG members may perform refreshment for the terminal that has radio bearers; the APG-ID is not changed.
- For inter-NSC mobility, the APG should possibly be moved from one LSC to another that is connected to a different NSC, assuming that the APG-ID is unique within one NSC.
- For inter-NSC mobility, or the mobility between UUDN and the traditional cellular network, the APG handover procedure is applied, for example, from one NSC to another NSC, or from one NSC to another traditional cellular network.

Figures 4a and 4b show typical DAPGing scenarios. In DAPGing, each APG-ID represents an APG. Every terminal acquires a unique APG-ID when a terminal attaches to a UUDN network. For example, user A has an APG named GA, and it always follows user A's movement for different time points t1 and t2, supported by a different combination of APs at each time point. The related radio bearers are also shown for each time point. However, the refreshment of GA is transparent to terminal A. For user B, which is stationary in this example, its APG (GB) is also refreshed at different time points t1 and t2, due to the adjustment of resource allocation.

In UUDN, terminals enter idle mode to save battery when there is no user data for transmission. For a terminal in idle mode, there are two methods to reach the terminal when mobile terminated service arrives. With the first method, a terminal periodically monitors whether it has moved out of the coverage of one or more AP members in its APG. If the answer is yes, the terminal updates this location to the network and triggers APG refreshment. In this case, the current APG-ID of this terminal and its AP members' information are stored within the network (e.g., in the NSC). The paging is triggered when mobile terminated service arrives, and paging messages are sent to the APs of the current APG-ID to let the AP page the terminal in the air. This method basically inherits the idea of a cellular system, which has been proved to have reasonable signaling efficiency.

In the second method, the terminal periodically sends out pilot signals to the network, to let the network update its location. Such updating may result in APG refreshment. When the mobile terminated traffic arrives, the network could communicate with the terminal directly without using a traditional paging process. This method may result in more terminal power consumption, but provide quicker response than the first method.

Joint Optimization of Resource Management and Interference Control

The resource management and interference control in UUDN face great challenges. The existing schemes in traditional cellular networks could not fulfill the requirements in UUDN. With effective cognition of a user's environment, resource management would jointly consider interference control as well as other important factors such as wireless channel, network available resources, users' mobility, and traffic features. The relative directions may include, but are not limited to, the following points:

- Resource allocation for the APGs, and inside an APG under the UUDN architecture.
- Cooperation among APG, users, and APs. Cooperation inside the groups is also very important.
- Fast APG refreshes and accordingly resource re-allocation during users' moving trace.
- Load balancing among APGs, inside an APG, and among users.

Accordingly, here we analyze and propose the possible approaches from the network and user sides with two different methods.

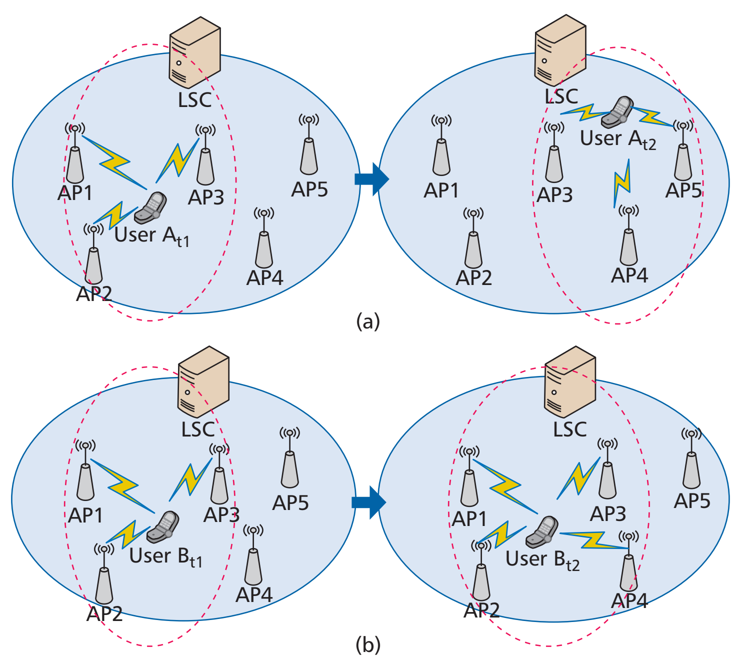
When there are sufficient available resources and function support from the terminal, the resource allocation may be fully distributed. Otherwise, negotiation models should be introduced, such as cooperative game theory among APGs or among users. Under this approach, the network side will not join the resource allocation process, which means that the algorithms should be fully distributed and adjustable. Also, the APs should be capable of environment sensing on idle channels, interference levels, and neighbor APs' conditions. The advantages of this approach include high efficiency of local resource management and real-time fulfillment for the users' requirements. However, its disadvantages are also obvious. The processing complexity will impact the resource allocation efficiency. Also, the requirements will be very high for the environment cognitive ability of APs.

The second approach needs the network side to participate and to offer center control to a certain degree. A local control unit in the LSC maintains the resource list in the neighbor areas, such as an available resource pool. The APs may get the information by periodic broadcast or dedicated request. Once there is need for transmission, an APG would select the proper resource from the pool; the resource list kept by the LSC may change accordingly. If there is contention in the resource allocation, the LSC has the arbitration right. By this approach, the resource management may achieve optimization by avoiding resource contention and decreasing interference. The disadvantage is that it is hard to determine the neighbor area of the resource list in real cases.

As we have discussed, these two approaches have different features. When we jointly handle the interference control problem, situations become more complicated. Traditional interference management includes interference concealment and interference alignment, interacting with synchronizing, cooperation, and signaling overhead. Corresponding to the two resource allocation approaches mentioned earlier, interference control may be added into the design. In the first approach, interference evaluation models should be added to the negotiation schemes as well as the environment sensing procedure. These models need further investigation in the UUDN scenario and may directly influence resource allocation results. In the second approach, the avail-

Mobility scenario	Approaches	Description
Intra-LSC, inter-LSC	APG refresh	By changing an APG member, the radio links between terminal and APs may be moved from one AP to another.
Inter-NSC	APG handover	The intra-NSC APG-ID is unique; thus, the terminal will get a new APG-ID when it moves to a new NSC. AP members will also be re-organized.
Mobility between UUDN and traditional cellular system	Handover	Handover to and from, or between UUDN and traditional cellular systems.

Table 3. Mobility scenarios and related approaches of UUDN.



	Time point	AP1	AP2	AP3	AP4	AP5
User A's APG	t1	√	√	√		
	t2			√	√	√
User B's APG	t1	√	√	√		
	t2	√	√	√	√	

Figure 4. Typical DAPGing scenarios: a) APG refresh by terminal mobility; b) APG refresh by resource management and other factors.

	Traditional solution	UUDN
Network architecture	Network-centric Cellular structure Light L-GW + heavy backhauling	User-centric De-cellular structure Fat local access server + flexible backhauling
Serving entity	Single serving BS	A dynamic APG
Mobility management	Handover and terminal involvement	Dynamic grouping and terminal unconsciously
Network sensing	Incapable	Capable
Radio resource management	Independent cell unit	Cooperation, user-centric
Interference management	Independent cell unit	Cooperation, user-centric
Security	Authentication repeat or frequency	Authentication relay or inheritable

Table 4. Comparison between UUDN and the traditional solution.

able resource list could have the item/entry of interference impact, or even occupied resources of the neighbors, to provide more details for the AP in choosing proper resource. This requires effective information collection of the real-time local resource condition. For the joint optimization of resource management and interference control, when considering implementation, other factors should also be included in the design, such as transmission efficiency, algorithm complexity, and signaling overhead.

Security

The security of UUDN, characterized by a serving user with APG, faces a variety of challenges. The security model must be elaborately designed under the new architecture of UUDN as per the following:

- An AP joining the specific APG as a member must be authenticated by the network, so as not to be counterfeited. The UUDN will provide security guarantees for UE and all of the members in the APG by new methods.
- A more flexible authentication mechanism for UUDN should be applied when the APG refreshes. When UE accesses UUDN through a certain APG, mutual authentication should be used. The authentication result of the trusted UE will be smoothly inherited among the APG so that other members of the APG can recognize and trust it.
- The key agreement mechanism of UUDN would be enhanced. A UE would apply for authentication to the APG instead of to an AP. The ciphering and integrity keys will be generated between the APG and UE, but the keys do not simply "share" within the APG. The enhanced key agreement mechanism should keep the security within UE and each member of the APG by the inherited or "shared" key seed. When one UE accesses or leaves a certain APG, the ciphering and integrity keys will be generated or revoked.
- The selection of a security model of UUDN should be a trade-off between communication quality and authentication efficiency under the computing cost constraint. Reference [15] points out that an accurate analysis in the standard AKA protocol signaling can provide insights into reducing loads in the authentication signaling.

The new security mode in UUDN can build "certified virtual communities" and provides a safe network environment "following and serving" the mobile user. The APG will provide lightweight and inheritable authentication services. When a UE passes authentication from one member of the APG, it will be trusted by the whole group. Based on this method, we can provide the "accompanying" authentication services, when the group is refreshed, to ensure uninterrupted high-speed traffic.

Summary

Following the user-centric philosophy, a new UUDN architecture with the de-cellular method is proposed to offer better services to users. In this architecture, two levels of service center and data center are introduced to provide the control plane and the user plane from the local and network sides, respectively. We propose DAPGing as the core function of UUDN. It is close to the user-centric mobility management function, and has direct impact on joint-optimized schemes of resource management and interference control.

A comparison between UUDN and the traditional solution is shown in Table 4.

Conclusion and Future Works

UDN is a promising solution for 5G. Based on the analysis of its features and typical scenarios, we define UUDN by introducing the de-cellular method. Then we thoroughly discuss the key issues in UUDN, including network architecture, mobility management, resource management, interference management, and security. We propose a possible solution accordingly. There are many interesting problems in UUDN to be discussed in detail.

For future work, besides further investigation of the aforementioned issues, we also identify other interesting research areas in UUDN, such as the ones below

For users, networks, and services, mobility behavior provides fundamental characteristics and rules in the temporal spatial and social dimensions. In UUDN, mobility behavior is an important factor that should be considered in optimizing overall performance of the system.

For very high density deployment scenarios, it is very difficult to connect each AP with ideal wired backhaul. A flexible backhauling to support ideal/non-ideal, wired/wireless backhaul is very important to ensure the deployment of UUDN.

Heterogeneous and cooperative networking is another problem to be further investigated. It is a big challenge to support UUDN with a complex multi-tier scenario, multi-RATs, and irregular coverage.

In the UUDN scenario, the use of mmWave bands is a promising way to provide very high data rate with very wide bandwidth. Many new features will be introduced due to very high frequency band, such as beamforming, coverage enhancement, integration of high and low band networks, and so on. Those will impact mobility management, interference management, and radio resource management.

The user's privacy is another key issue. The method of user authentication is essential for users' privacy protection. Multiple lightweight and integrated security technologies are needed. It will be important for UUDN to archive lightweight authentication and combine other security technology to provide end-to-end security.

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The method of user authentication is essential for user's privacy protection. It needs multiple lightweight and integrated security technologies. It will be important for UUDN to archive the lightweight authentication and combining other security technology to provide end-to-end security.