# A Converged Network Architecture Oriented Towards NB-IoT

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**Abstract.** Although NB-IoT's standardization gives us a future direction, we have to face some issues of existing networks converged, especially, the wireless sensor net-work (WSN) and cellular networks (CN) converged. On the other hand, the increase in number of sensor nodes and in the mobile devices is forcing the backhaul network architecture to undergo radical transformation. To meet the requirements of low latency and high quality of service (QoS), we put forward a novel converged network architecture. Meanwhile, we give three application scenarios. The analysis results show this architecture could facility the network design.

**Keywords:** 5G · Narrow-Band Internet of Things (NB-IoT) · Wireless sensor network · Network architecture · Heterogeneous network

## 1 Introduction

With the developments of the Internet of Things (IoT), the Internet of Everything is gradually from research to application [1–5]. However, the current 4G network is lack of capacity, which achieves to connect between the things and things. In fact, to compare to Bluetooth, ZigBee and other short-range communication technology, the mobile CN have some novel features, which involves the wide coverage, the mobility, the massive connectivity, as well as abundant application scenarios [6]. As the evolution of LTE (Long Term Evolution) technologies, 4.5 G has a peak rate of up to 1 Gbps, which means more connections based on the number of cellular networking. It supports mass M2M connectivity and lower latency. These characteristics will promote the rapid applications of HD video, VoLTE, as well as IoT. Fortunately, recognizing the importance, 3GPP has introduced a number of key features for IoT in its latest release, Rel-13. EC-GSM-IoT [7] and LTE-MTC [8]. Then, in the Third-Generation Partnership


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Project's (3GPP's) Radio Access Network Plenary Meeting 69, the Narrow-Band Internet of Things (NB-IoT) is decided to standardize [9]. This standardization will focus on providing improved indoor coverage, supporting of a massive number of low-throughput devices, low latency sensitivity, ultra-ow device cost, low device energy consumption, and optimized network architecture.

Although NB-IoT's standardization gives us a future direction, we have to face some issues of existing networks converged, especially, the wireless sensor network (WSN) and cellular network (CN) converged. This is due to that, WSN have been generated an increasing interest from industry and research perspectives, and played a vital role in many fields, i.e. e-Health care [10], environment monitoring [11], industrial metering [12], surveillance systems [13] etc. WSN can be generally described as a network of nodes that cooperatively sense and may control the environment enabling interaction between persons or computers and the surrounding environment [14]. On the other hand, the convergence application of WSN and CN will become brighter and inevitable. Heterogeneous networks consisting of CN and WSN appear in many application areas. Many dedicated mobile phones are equipped with a WSN air - interface for technology testing, evaluation and demonstration purposes. These mobile phones can collect measurement data from a variety of sensor nodes and then forward this data to an information center of the CN. In such a case, CN is simply used as a backhaul infrastructure for WSN, i.e. there is no dynamic interaction between both networks.

To meet the requirements of WSN and CN converged, a novel converged network architecture of WSN and LTE-A is proposed in this paper. The rest of this paper is organized as follows. In Sect. 2, some related works are investigated and reviewed. In Sect. 3, our converged network architecture is proposed and analyzed. In Sect. 4, the future researches are described. At last, the conclusions are given.

## 2 Related Works

Modern technologies have been prepared for creating the convergent communications infrastructures of WSN and CN, which the WSN and CN have become a worldwide standard, with unprecedented levels of coverage, reliability and affordability. In this section, we discuss the research on the architecture and topology of WSN, cellular and the others.

In terms of the convergence of heterogeneous network, Deokhui et al. proposed a converged architecture for broadcast and multicast services in a heterogeneous network [15]. This architecture could efficiently support the broadcast/multicast services in LTE network. Malhan et al. presented the converged architecture, and analyze various services which are running on it along with the understanding of their characteristics [16]. Zhang and Liang proposed a new architecture for converged Internet of things based on Vector Network (VN) [17]. Tzanakaki et al. put forward a converged network architecture for energy efficient mobile cloud computing to satisfy the low-latency requirements of content-rich mobile applications [18]. Gercheva et al. summarized the benefits of converged next generation network architecture to meet the demands of latency and service quality requirements [19].

There had been a large amount of researches in creating WSN network structures (i.e. Flat or Hierarchical) [20]. In the hierarchical architecture, grouping sensor nodes into cluster had been widely pursued in order to achieve the WSN scalability objective. In each cluster, a sensor node was selected, termed as the Cluster Head (CH). Then, these cluster heads collected sensor data from other nodes in the vicinity and transmitted the aggregated data to the Gateway (GW). The CH was responsible for not only the general request but also receiving the sensed data of other sensor nodes in the same cluster and routing (transmitting) these data to the gateway. Thus, the CHs had higher energy cost because all of the transmitting data packet would pass through them and be sent to the gateway. And so, the CH selection was very important for WSN. In the next section, we will give a novel network architecture based on convergence of WSN and LTE-A.

## 3 Convergence of WSN and CN

In this section, we analyze the objectives of the integrations and three different application scenarios, and then propose the converged network architecture.

### 3.1 Objectives of Convergence

The primary objective of the project is to design a WSN fixed/mobile gateway including transmission path selection, mobility management and breakthrough access control signalling. In this research, we propose WSN-CN convergence strategies for connection-oriented, lifetime-oriented and hybrid deployment, where a mobile terminal used as a gateway for sensor nodes to transmit the detected data to backbone database under the help of 3GPP-LTE basic station (eNodeB). Therefore, this sensor network gateway is required to provide wireless interface(s) to other sensor nodes as well as the air interface of a mobile network system (e.g., 3G/3GPP/WiMAX) to the existing network infrastructures. The information from sensor network and CN will be merged autonomously. Therefore, the sensor networks cover the detecting area; while the CN will also cover this area and can help the sensor networks to acquire better transmission quality. The sensor networks MAC/Routing protocol design and some resource management algorithms/routing algorithms can be completed under the 3GPP-LTE eNodeB assistance. All the results from this research will provide a viable solution for the problem of optimizing provisioning of a large scale heterogeneous WSN and CN. The detailed objectives of the project are:

- Design a breakthrough control signaling between the gateway (including mobile and fixed gateway) and 3GPP-LTE eNodeB, gateway and common WSN nodes.
- MAC/Routing protocol design, including WSN fixed/mobile gateway selection and re-selection under 3GPP-LTE eNodeB assistance.

Research mobile management of gateway and resource allocation mechanism to guarantee the communication QoS.

### 3.2 Application Scenarios

Potential challenging of the Integration Potential impacts at high level to the LTE-A systems of signalling, protocol stacks etc. from a terminal point of view. This scenario considers a cellular system in which cellular UEs are under the control of the eNodeB.

In the coverage area, there exists a group of wireless sensor nodes constructing a WSN. In this area, it includes two types of gateways: fixed gateway (box in the figure) and mobile gateway (acting as cellular UE), which is shown in Fig. 1. All of the WSN gateway in the cell can provide the access for the WSN nodes, and all gateways are dual-mode and have WSN and CN interfaces. Then, the data from WSN can be directly forwarded to the eNodeB by the gateway. The normal mobile UE can also acquire the necessary information with the downlink data transmission from the eNodeB or from the other fixed/mobile gateway.

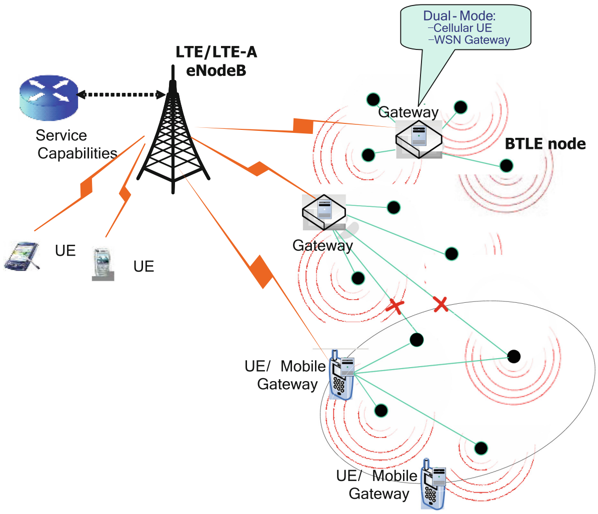


**Fig. 1.** System application scenarios

The application scenario is divided into three types:

UC1: UE overhears the WSN traffic and reports to eNodeB;

At the beginning, all the nodes are sleeping and BS doesn't have the detail information of these nodes. Then a UE will collect the information from these nodes. When the UE entries this zone, it begins to overhear the downlink control signalling, if it hears the control signalling, then it will wake up the nodes within its maximum communication range under the permission of the BS. After receiving the broadcast message from UE, the nodes wake up and send their reply to UE. Then the nodes will choose the optimal path to form the network. After the network is formed, UE sends the information of all the nodes in the network to BS. And it is ordered the sensor nodes collect data from them to BS in periodical or event-driven mode, which is shown in Fig. 2. After some time, UE maybe leave this zone, it cause the mobile gateway selection/reselection.

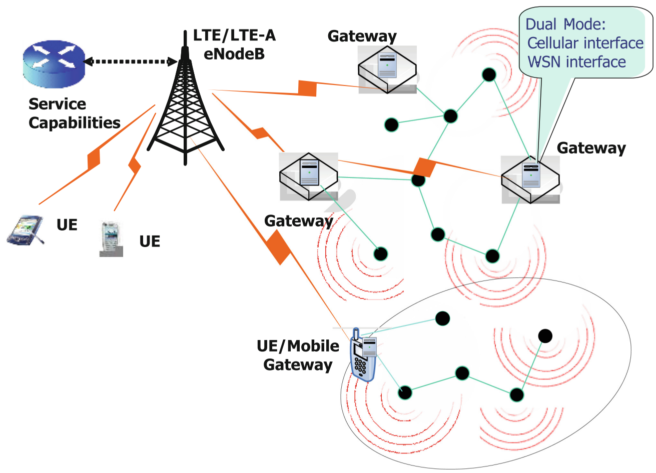


**Fig. 2.** UE overhears WSN application scenario

UC2: UE acts as mobile gateway of WSN (replacement/reselection or splitting);

After a UE acting as new mobile UE gateway enters the coverage of the WSN, it may cause the gateway (re)selection or even regrouping of the wireless sensor nodes, which is shown in Fig. 3. How to make a balanced trade-off between the complexity, performance gain and energy consumption etc. via a robust (re)selection and grouping algorithms is an essential issue for further study. Research the gateway (re)selection algorithms and sensor nodes grouping algorithms when certain UE gateways are arriving at the coverage of the WSN become the other important part.

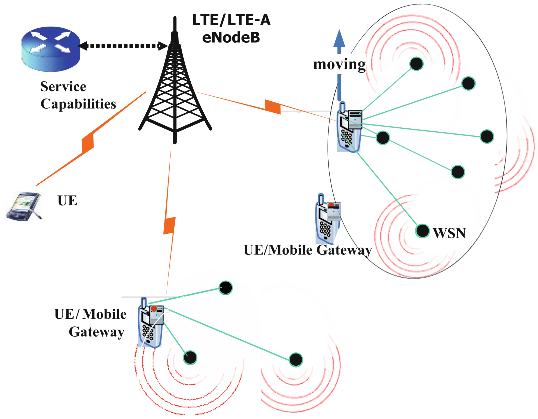


**Fig. 3.** Mobile UE gateway replacement

In the splitting task, we design load-balancing mechanism among different UE gateways and adjust the connected number of wireless sensor nodes in order to avoid the transmission congestion and decrease the transmission delay.

UC3: UE activates/deactivates WSN;

The mobility management of UE gateway is quite different with the conventional UE mobility in the 3GPP-LTE systems. This scenario is based on the mobile UE gateway providing the convergent access function for the WSN nodes. During the moving process of mobile UE gateway, it will enter/exit a WSN area, where the sensor nodes' convergence point is this gateway and the WSN sensor nodes will be activated/deactivated by the UE gateway, which is shown in Fig. 4.

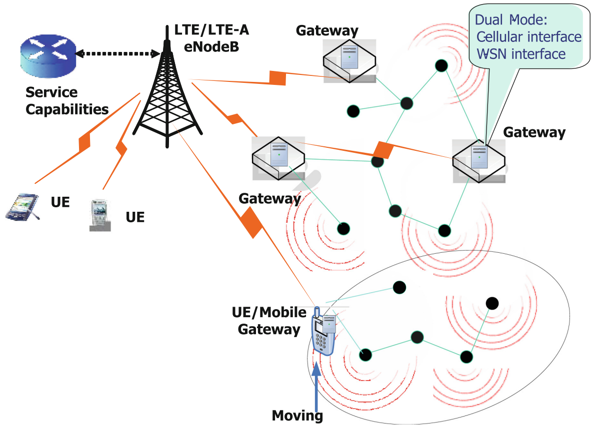


**Fig. 4.** UE activates/deactivates WSN

In fact, the BS doesn't know the exact position of the nodes but we know the general position of the nodes and the range of the dead zone. We can first select several positions, and the total communication range of UE should cover the range of the dead zone. After UE entries the dead zone, it will listen the downlink control signalling and set the broadcast message. Then the nodes will choose the optimal path to form the network. After the network is formed, UE sends the information of all the nodes in the network to BS. After collecting enough information, it moves to the next position and re-forms the topology of the network.

### 3.3 Converged Network Architecture

As WSN are being developed for a wide range of application fields of real-time monitoring and control, a design overview seems important so as to investigate alternative communication aspects while treating WSN as a whole system. As applications become more demanding the need to consider also deployment constraints and application particularities on top of the commonly used network factors, leads to new integrated design methodologies for addressing all complexity degrees of such systems.

The conventional network architecture of integrated CN and WSN is hierarchical, as shown in the left part of Fig. 5. All gateways are dual-mode and have both WSN and CN interfaces. A group of wireless sensor nodes constructs the data detecting plane, while the gateway and the base station (BS) comprised the system control plane. The WSN is controlled indirectly by the BS through the gateway. The gateway can just provide the access for the WSN nodes, and forward the detected data to the backhaul networks servers. Communications between WSN and CN use a data channel at the gateway, which however decreases the system efficiency. As shown in the right part of Fig. 5, in the network architecture, the sensor nodes may have the ability of hearing the downlink signaling from the UE gateway of CN. For the uplink, due to the limited transmission range of sensor nodes, the data is routed by the gateway.

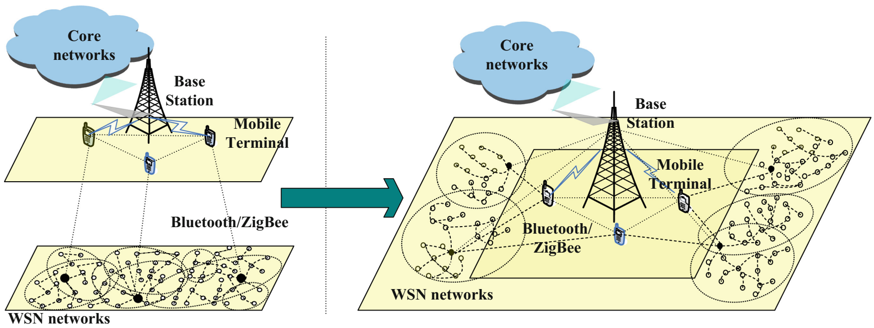


**Fig. 5.** Network architecture for CN and WSN

## 4 Future Directions

Considering the 3GPP-LTE eNodeB acting as database server, the routing table design including storage, updating and sharing between nodes needs to be further studied when considering the cellular and WSN convergence. The sensor networks transmission path database and topology information changing will become the other important part for the task of WSN gateway selection. We should research the transmission path and topology change with the mobile UE gateway entry/exit, and the routing table storage and maintenance methods. Research on the network and link layers of the WSN protocol stack has had as its main motivations the architecture and protocol design, energy conservation, and location. Although only a few studies concerning QoS in WSN have been performed, there are several very interesting works regarding QoS. An exact definition of QoS in the WSN context should be provided in the further study.

## 5 Conclusions

From this converged network architecture and other previous studies, we could think that the convergence of WSN and CN can benefit both of the two types of network. For WSN, the CN can enable higher layer control and optimization to prolong the network lifetime, improve the WSN system performance and provide QoS for WSN services. For CN, WSN can enable the cognitive and intelligent aspects of the cellular system. It is envisaged that converged network architecture of WSN and CN could enable better wireless services and more data-centric applications. On the other hand, the CN can control and manage attached WSN, thus making WSN more efficient in energy saving and performance improvement. Moreover, WSN can enrich mobile applications and provide real-time measurement data for network performance and service coverage optimization in CN. As for the telemetry and remote management of distributed assets, the convergence of WSN and CN can be used in the supervisory control and data acquisition system. WSN in these applications need to be managed and optimized with the aid of CN. Hence, enabling technologies needed to be researched and developed for interactive control and joint optimization of converged CN and WSN.

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