University of Colorado
Interdisciplinary Telecommunications Program
TLEN 5700

Project Definition Document (PDD) v.2.0

Wireless Proximity Communication System (WPCS)

Approvals

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
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<tr>
<td>Customer</td>
<td>Kevin Gifford</td>
<td>CU Boulder ITP</td>
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<td>Course Coordinator</td>
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Project Customers

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1.0 Problem or Need

Wireless communications are vital for critical operations such as public safety, disaster control and space communication. First responders require a device that allows interoperability between various safety agencies like Offices of Emergency services (OES), emergency medical providers and Ambulance, etc. Deployable systems are often utilized to expand wireless coverage to geographical areas that are unserved by fixed tower sites or provide network coverage to areas that do not have the permission to install towers (e.g. national parks). These systems must be easily configurable and deployed in a short span of time (say 10 minutes), and must address the inter-working between a deployable system and a fixed eNodeB as required by the Nationwide Public Safety Broadband Network (NPSBN) [1].

The Wireless Proximity Communication System (WPCS) project will design a test bed for high data-rate communications using LTE technology that is vendor-neutral, which implies that it must focus on establishing a successful communication between the User Equipment (UE), irrespective of the manufacturer of the UE or the virtual Evolved Packet Core (vEPC) or the eNodeB (both fixed and mobile). The UEs need to support a wide variety of LTE frequency bands so that proper channel selection can be done. This project will make use of the 2500 MHz Educational Broadband Services (EBS) spectrum. The test bed will allow the UEs not only to communicate with each other within the network, but also to send and receive data from the internet.

The project, upon successful implementation, will allow the first responders or any customer to deploy the LTE system without being limited by vendor specifics. The setup provides a seamless handover between the fixed and deployable eNodeB(s). Also, the setup allows seamless integration of the deployable system into an existing fixed network architecture. The goal is to allow communication across various devices consistently, especially during an emergency.

2.0 Previous Work

Several companies have implemented test beds with varying capabilities. In the early 2000s, Ericsson had implemented a test bed with a single cell configuration. While the test bed was scalable, it did not support Radio Resource Management (RRM) and cellular hand-off [2]. Furthermore, companies such as National Instruments have carried out research to develop a test bed that includes Wi-Fi along with cellular capabilities [3].

Studies from the National Public Safety Telecommunications Council and the Defense Research and Development Canada’s Centre for Security Science report the various scenarios for implementing a LTE Broadband Deployable systems (BBDS) for public safety [4]. The implementation allows for a seamless transition of voice and data services and handoff from one network to another. In addition, LTE devices of responders must be able to connect to the BBDS along with providing location based services. The BBDS is made operable by carrying in a bag, used in vehicles/towers or in an aerial mode. However, care must be taken to ensure that the deployable systems do not interfere with each other and communication is established between devices in a 3GPP network and a non 3GPP network.
Recently, NIST has been deploying LTE systems for public safety purposes [5]. The Public Safety Communications Research Division at NIST points out that these deployable systems need to be used in areas affected by natural disasters or heavy congestion, and regions with limited backhaul connectivity or without network access [6]. The main aim of the research is to provide full mobility across a dynamic network with interference mitigation.

While the focus of other projects has largely been public safety, this project emphasizes on the creation of a test bed for versatile implementations such as space communications and research/testing of additional applications such as Device-to-Device communications and ad-hoc roaming relationship between cores, apart from public safety. The WPCS aims at being vendor agnostic and easily upgradable for future enhancements.

3.0 Specific Objectives

Objectives
This project will

- integrate fixed and deployable radio heads with the network core
- provide a proximity high data-rate communications testbed for supporting public safety research activities
- facilitate Device-to-Device interoperability
- identify subsequent design methodologies and future research activities to best extend the architecture to support other projects such as NASA Explorations and Operations Missions

Levels of Success
Level 1: vEPC Selection
There are a variety of EPCs available in the market and the initial design constraint is to choose the best EPC that fits the need for the project. The requirements that go into choosing the EPC are identified as below [7]:

- Cost
- Replication
- Number of eNBs supported
- Is it Vendor-specific
- Core-Core connectivity
- Duplex modes
- Availability of technical support
- Support for Airspan eNBs

Level2: Connectivity between the fixed EPC and the eNB
In addition to complying with the Level-1 criteria, the fixed eNB for this project is required to be the Airspan Airsynergy-2000. Various components within the EPC such as Home Subscriber Subsystem (HSS), PDN Gateway(PGW), Mobility Management Equipment (MME),
Serving Gateway (SGW), Policy and Charging Rules Function (PCRF) will be configured individually and the resulting configuration will match with the eNB configuration. MME will be configured to provide Radio Resource Management (RRM) and bearer service between the eNB and the core. HSS will be updated with the UE information so that the UE could access the internet through the subsystems. SGW will be configured to route the data packets through the PGW, and in turn to the internet. The rules and policies required to maintain the UE in the “_CONNECTED” state or “_IDLE” state will be configured on the PCRF. The EPC will also be connected to the Layer-3 network devices so that the PGW has a backhaul to the internet.

**Level3: Adding a Deployable System to the network**

In addition to complying with the Level-2 criteria, this project will choose a deployable eNB system that could be added to the design. The deployable system would either have its own EPC or could use the already selected EPC. In the former case, the interconnectivity between the cores would be established, so that there is no loss of connectivity when moving from one eNB to another. In the latter case, the S1 protocol stack will be configured with the Mobile Country Code (MCC) and Mobile Network Code (MNC), so that the S1 interface between the EPC and the deployable system is seamless. The deployable eNB will enable the testing of X2 interface and the subsequent handoff associated with it.

**Level4: CU-Boulder and SFU connection validation**

In addition to complying with the Level-3 criteria, connection will be established between the UE at CU-Boulder and the UE connected to an alternative test bed at Simon Fraser University, testing the configuration of every subsystem and the corresponding interfaces. The final deliverable will validate the setup and will help in realizing the LTE testbed architecture as a proximity high-data rate setup.

### 4.0 Functional Requirements

The project aims to develop a communication test bed that is easily configured and deployed in a short time span. It must also support interoperability between the various components of the system.

**Hardware components:**
- Fixed eNodeB
- Deployable system (mobile eNodeB)
- User Equipment (UE)

**Software components:**
- vEPC
- Interface design
**Definition of the components**

**eNodeB (eNB):** The eNodeB is a base station that communicates with the mobile devices (UEs) and the Evolved Packet Core (EPC). Essentially, the eNB provides the air interface between the UEs and the core network. Each eNB is connected to the core via an interface called the S1 interface and communications between the eNBs are through the X2 interface, which are used for signaling and packet forwarding during handover.

**Deployable system:** Also called Cell on Wheels (COW), the deployable system is a mobile eNB that provides LTE network coverage in an area where there is no cellular coverage from the towers. It is extremely useful in a disaster recovery scenario as it allows the first responders to effectively communicate with each other [8].

**Evolved Packet Core (EPC):** The EPC is the core network that allows the UE to connect to the internet. It consists of several components such as the Mobility Management Entity (MME), Home Subscriber Service (HSS), Serving Gateway (S-GW), Packet Data Network Gateway (P-GW).

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**Figure 1: Functional block diagram of the WPCS test bed**
- MME - controls the high-level operation of the mobile by means of signaling messages between the UEs and the Home Subscriber Server (HSS)
- S-GW - acts as a router, and forwards data between the base station and the PDN gateway
- P-GW/PDN-GW - communicates with the outside world i.e. packet data networks PDN, using SGi interface. Each packet data network is identified by an access point name (APN)
- HSS - is a central database that contains information about all the network operator’s subscribers

User equipment (UE): The device that allows a user to originate and terminate any communications with the LTE system.

Concept of Operations (CONOPS) diagram

![Concept of Operations Diagram](image)

*Figure 2: Shows the concept of operations of the test bed [9].*

5.0 Critical Project Elements

Technical:

1. **Selection of vEPC:** This is a key component in the design architecture and will impact the selection of the deployable system and the connectivity with the fixed eNB.
2. **Subsystem Configuration:** The various subsystems in the EPC need to be carefully configured so that the design elements meet the requirements of the attached eNB.
3. **Core- Core interconnectivity:** If the deployable system has a separate core, the interconnectivity between the cores is highly critical for the system to function properly. The X2 interface must be designed carefully so that there is a handoff between the eNBs.

**Logistics:**

1. **EBS-BRS spectrum usage:** The spectrum needs to be swept to check if there are any potential interferers to the setup being designed. Also, the required permission must be obtained in prior, to use the bands.

2. **Size of Hardware:** There is a potential to expand the area of coverage of the test bed radios by moving the deployable system farther from the EPC setup in the lab. This could also help test the handoff of the UEs. As a result, the deployable system should not be very big or heavy and must be little easy to carry around.

**Financial:**

1. **Cost of vEPC:** Cost is an important feature in the selection of an EPC and it should also be freely replicable so that no additional licensing costs are incurred.

2. **Cost of Deployable System:** The deployable system chosen should also be cost-effective and easily configurable.

### 6.0 Team Skills and Interests

**Vijay Krishnan:** Vijay has worked over the summer on a NASA-sponsored project to expand wireless communication external to ISS and, has developed an interest in setting up a test bed for a wireless system. His internship at CableLabs has emphasized the importance of a network architecture and his previous experience with the “Airsynergy eNB- Aricent EPC” has provided technical background and expertise for configuring the system as a whole.

**Siddhartha Subray:** Sid had previously worked on setting up an LTE system using a fixed eNB and an Aricent EPC, configuring both the eNB as well as the EPC. He has also worked on a NASA project to simulate and improve the external wireless communication system on the International Space Station (ISS). His experience and skills with the LTE system and his background in wireless communication enables him to be a suitable candidate to work on this project.

**Shruthi Prasad:** Shruthi has been associated in the field of Wireless Communications for the past year. Her focus has been more towards Wi-Fi. She interned with Charter Communications over the summer which gave her an opportunity to improve her programming skills, gain knowledge about the cable industry and develop an experience in an agile environment. Her interaction with her peers has given her a good insight and the basics required for the project. Her keen interest in LTE, along with her interpersonal skills will make her a good fit for the project.
### Critical Project Elements

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<th>Team member(s) and associated skills/interests</th>
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<tr>
<td>LTE know-how</td>
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<tr>
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<tr>
<td>Validating the test-bed</td>
<td>All Team Members</td>
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#### 7.0 Resources

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<tr>
<td>LTE know-how</td>
<td>Thomas Schwengler, Dr. Kevin Gifford</td>
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<tr>
<td>Selection of vEPC</td>
<td>Micheal Sherman - Rutgers University, Nokia Small-Cell Newsletter, NIST/NTIA, Major Wireless Carriers like AT&amp;T, Verizon, Sprint and T-Mobile.</td>
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<td>Configuring eNB-EPC setup</td>
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<td>Validating the test-bed</td>
<td>Thomas Schwengler, Dr. Kevin Gifford, Simon Fraser University test-bed support, Dr. Eric Anderson</td>
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#### 8.0 References


Test bed requirements:

1. The test bed shall be designed so that it is rapidly deployable
2. The test bed shall be designed to enable easy integration into an existing infrastructure
3. The test bed shall be designed to ensure reliable connection for the UEs
4. The test bed shall allow seamless handover of UE from one eNodeB to another
5. The test bed shall be designed to support open standard internetwork mesh connection
6. The test bed shall support interoperability between the network components
7. The test bed shall have a deployable system without a built-in EPC
8. The test bed shall allow the UEs in the network to communicate with each other

Design drivers:

1. The system shall be vendor agnostic
2. The vEPC must be replicable without any cost
3. The vEPC must be upgradeable to incorporate future technologies