

ATLANTA, GA OCTOBER 11-14



# UNLEASHTHE POWER OF IMITLESS CONNECTIVITY





### Wireless Access Network

## Network In A Box

**Joerg Ahrweiler** 

Director Wireless R&D Charter Communications



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- The Network In A Box (NIB) definition started with a 4G network that is operating the core network and base-station in a single box that is portable and self-organizing, which provides seamless connectivity to a group of mobile users, offering services such as internet connectivity and closed group communication (Push To Talk/Video/Text).
- It expands cellular network coverage in various environments and different use cases, such as terrestrial disaster relief, private networks in-flight, at sea and in other scenarios and environments where an ad-hoc cellular network is required.
- The NIB concept is a miniature evolution of the traditional cell on the wheel (COW) concept that has been widely used for cellular mobile voice communication.



The network architecture shows the traditional 4G network architecture with a CBRS environment. The RAN (Radio Access Network) and CN (Core Network) architecture in the NIB setup is very much like the traditional LTE network in commercial solutions; main difference is the small-scale nature of the setup. Since the use of the frequency band B48 (3550 MHz – 3700 MHz) is ideal for the NIB approach – shared spectrum/no spectrum needs to be owned – the connectivity of the NIB setup to a SAS (Spectrum Access System) is mandatory





## 'Off the shelf eNodeB

#### LTE eNB Equipment Specifications

Specification	Value
Product	LTE Pico eNB
Band Support	B48 (3.55 – 3.7 GHz)
Carrier Aggregation	Up to 3 CA (only 1 Carrier used in NIB setup)
MIMO	2x2
Frame Configuration	TDD Frame Configuration 2 Special Sub Frame 7
IBW/OBW	150 MHz / 60 MHz
Output Power	2 x 250 mW (max), actual 2 x 25 mW
Antenna	Built-in average 0 dBi
Modulation QAM DL/UL	256 / 64
BF Capability	No
CBRS Classification	CBSD CAT A

- A commercial small cell Pico eNB is used
- Solution implementation proven working with multiple RAN vendor solutions
- The output power was limited to 14 dBm/25mW per antenna port but can be increased to 24 dBm/250mW if required for respective use case
- To be able to achieve ease of deployment, the eNB was put in 'free running' mode for synchronization

#### Core Network (EPC/HSS/PCRF)



## **Open Source Core Network**

The Core Network functions are established by utilizing an open-source application suite running on a bare-metal industrial small scale PC with a Linuxbased operating system.

There are nowadays many options of opensource EPC/HSS solutions, see below for a list (not conclusive) of most popular open source core network:

- Open5Gs Formerly NextEPC
- OpenAl Core Network Related to / branched from OMEC
- Magma Based on OMEC, with a focus on Fixed Wireless more than mobile
- OMEC Open Evolved Mobile Core
- OpenMME MME
- OpenCORD
- srsEPC

#### End To End NIB integration and setup





## **Network In A Box**

To be able to easily deploy the NIB, all the components are installed in a Pelican case for easy transportation.

Additionally an embedded screen and wireless keyboard/mouse are included in the setup.

Showing the industrial type PC, running the EPC/HSS and O&M functionalities, on the left side in the case. The right component in the case is the commercial Pico eNB.

Connectivity



## **Connectivity Interfaces**



- eNodeB is physically interconnected to the industrial PC via 2 \* RJ45 Ethernet cables => S1 & 0&M
- The O&M link is utilized to automatically control the bring-up and maintain the system.
- A third Ethernet interface on the industrial PC is for the Backhaul connectivity to the Internet (user traffic and SAS connectivity). The same function can also be established via an internal WiFi or (Commercial) Cellular module.



For the purpose of a 'zero touch' and controlled system boot-up, a software application suite was developed to overcome any possible grace conditions and system malfunctions while the NIB setup is coming in service. The application starts automatically after power-up of the NIB and observing the physical and functional status of all components. If a delay or intervention during the boot-up process is necessary, the application will do so. Once the system in completely in service and the Radio is On-Air, the user will be notified and the power-on of the end-user devices can begin.

The requirement was to automate all manual processes to start the private wireless network, known as Network in a Box. Therefore, the start mechanism has to follow the new concept of Zero Touch.

#### **Zero Touch Architecture**





## **Three Tier SW Solution**

- The presentation tier, or user interface
- The application tier, where data is processed
- The data tier, where the data associated with the application is stored and managed, is a well-established software application architecture that organizes applications into three logical and physical computing tiers.





## **Presentation Layer**

- Two applications: (1) one is a desktop application, (2) the second one is an android application.
- The desktop application runs on a ubuntu server:
  - Starts automatically when powered up.
  - Starts the private LTE components (MME, SGW, PGW, PCRF, and HSS).
  - Checks the log file for all of these components to ensure that each component starts correctly. It displays a block diagram to represent the elements of the network and it uses the color scheme to represent the status of each element as shown in the screenshots below.



## **Power-Up**

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NITER							C	RESTART	SHUTDOWN	
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- Initial status after power-up
- Next step wait for physical interfaces to come in service



## Interfaces In Service

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					RESTART	SHUTDOWN	
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PQRESErvice Status: Error* nettep:cprfd.sevide - NextEPC PCMS Duedon Loade: Loade: Loaded (/llb/ystedm/ysteen/sevide/pcff.sevice) enabled( Attiv: Inactive (dead) since The 2020-12-08 12:02:09 MST 55ms app Process: 1235 ExecStatrix/srbin/settepc-prfd -f /etc/nextepc/pcff.conf (cod Main PTE: 1553 (rodesavitad _status0/SE/FESG)	reset: enabled) e=exited, status=0/SUCCESS)						

- All Ethernet interfaces are in service
- Next step start of EPC/HSS services



## Starting EPC/HSS

\$							
	Config System	Stop Services	Check Interfaces	Start Services	eNB Status		
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					RESTART	SHUTDOWN	
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- EPC/HSS services started
- Next step activation of S1 link



## S1 link active

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H.	Status	rssi rsrr	RSSNR	Lovel	eNB	MME	HSS SGV	5 V	PCRF PGW		
									RESTART	SHUTDOWN	
endor preset: o	enabled)	since Thu 2020-	12-83 12:53:38 M	ST: 74ms ano							
Main PID: 213 Tasks: 1 (1 OGroup: /sys	9 (nextepc-mm limit: 4539) stem.slice/ne: 139 /usr/bin/	<pre>id) ktepc-mmed.serv1 hextepc-mmed -f</pre>	ice /etc/nextepc/mme	.conf							
Dec 03 12:53:30	0 epc-desktop	systemd[1]: Sta	irted NextEPC MME	Daemon.							

- S1 link is activated
- Next step wait for positive SAS communication and eNB to come On-Air



## System in service

<image/>	¢		
<form></form>		Control The network is up and running, please proceed and turn on the UEs 🛞	
VHUT Trestep://gk.comf ec 03 12:53:33 epc-desktop systems[1]: Started NextEPC P-OH Daemon. populageTs file To file 0 opping BTs file To file 0	ld Status RSSI RSRP RSSNR Level	ERSTARE	
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opping bits of the second seco	Dec 03 12:53:31 epc-desktop systemd[1]: Started NextEPC P-GW Daemon. updateUesLastLogs Devices =====> []		
	Copying BTS file BTS file 0 Copying BTS file Protest BTS Eth		

- System is fully in service and eNB On-Air
- User is notified that devices can be powered-on



## **UE/Device activation**



After devices are powered-on, the device table is activated and device status monitored



# UE/Device attached and reporting

Devices are successfully attached to the NIB network and the RF conditions reported and presented in the NIB portal





## **Client application**









## **Business Logic Layer**

- Three software components had to be used in this layer: ExpressJS, NodeJS and Puppeteer
  - Express is a Node.js web application framework that offers a comprehensive range of functionality for both web and mobile apps. Express adds a thin layer of basic web application functionality without obscuring the Node.js capabilities users already know and appreciate.
  - Node.js is a scalable network application builder that uses an asynchronous eventdriven JavaScript engine. Many connections can be handled at the same time in the "hello world" example below. The callback is invoked with each connection, but if there is no work to be done, Node.js will sleep.
  - Puppeteer is a Node library that provides a high-level API to control headless Chrome or Chromium over the DevTools Protocol. It can also be configured to use full (nonheadless) Chrome or Chromium.



## **Data Layer**

The following information is stored in the database:

- UeID: User Entity Identification
- RSSI: Received Signal Strength Indicator
- RSRP: Reference Signal Received Power
- RSSNR: Reference Signal Signal to Noise Ratio
- CQI: Channel Quality Indicator
- level: Battery Level
- timeStamp: Time Stamp

#### Zero Touch – Configuration Management



## **Configuration Management**

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ikovler <sup>1</sup>			RETURN TO MAIN CANCEL
aneral			
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enp6s0	erxid8eb07b316ff	wk3c3786d455ed	
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EPC Logs Base Path*	EPC Version*		
Ivarlog	nextepc		
	Please select your EPC eerston		
hecking Intervals			
Backhaul (MF) Treasur	BackHaut Interval	11 Internal	
Minutes: 2	Seconda: 60	Seconds: 60	
Cell Internal	EPC Service Interval	MME Log Interval	
Seconds: 60	Seconda: 60	Seconda: 10	
\$1 Interface delay			
Seconds: 30			

A Configuration menu had to be added for the user to be able to choose between which ENodeB is connected to the PLTE Core Network



## Mobile Edge Compute Use Case Examples

Beside generic end-user internet access, different options for MEC-based use cases were explored. The following lists two examples:

#### **Closed Group Communication**

Closed Group Communication aka 'Push To Talk/Video/Text' is an ideal communication method in an enterprise private wireless environment, e.g. factory, hotel etc... End users can be easily communicating with their respective groups (all or some at once or one-to-one), or a local PTx network dispatcher, by a push of a button. In our NIB solution, we installed a demo version the PTx server and dispatch applications in the MEC and respective PTx client application on the end-user devices.

#### Mobile Edge Compute Use Case Examples





## VR (Virtual Reality) low latency applications

- VR Workplace: Teleport to virtual office floor, Interact virtually with lab machines and sensors
- VR smart light control: Able the city workers to access Smart light for control and data retrieval using VR
- VR Healthcare: Control instruments remotely, read patient charts
- VR Industrial: Troubleshoot and analyze machine performance



- Network In A Box has a well-deserved reputation in the cellular industry. With the addition of 'zero touch' control and MEC in the same compute platform, the use for any users and many applications domains is opened up.
- Research and further development of NIB will continue which includes:
- Evolve to a 5G system, e.g. 5G n48 Pico eNB and a 5G SA Core Network
- Expand on the list of supported RAN vendors in the NIB 'zero touch' portal
- Migrate the CN to a virtualized/containerized implementation



ATLANTA, GA OCTOBER 11-14

# Thank You!

#### **Joerg Ahrweiler**

Director Wireless R&D Charter Communications 6360 Fiddlers Green Greenwood Village, CO 80111 720-699-3580





