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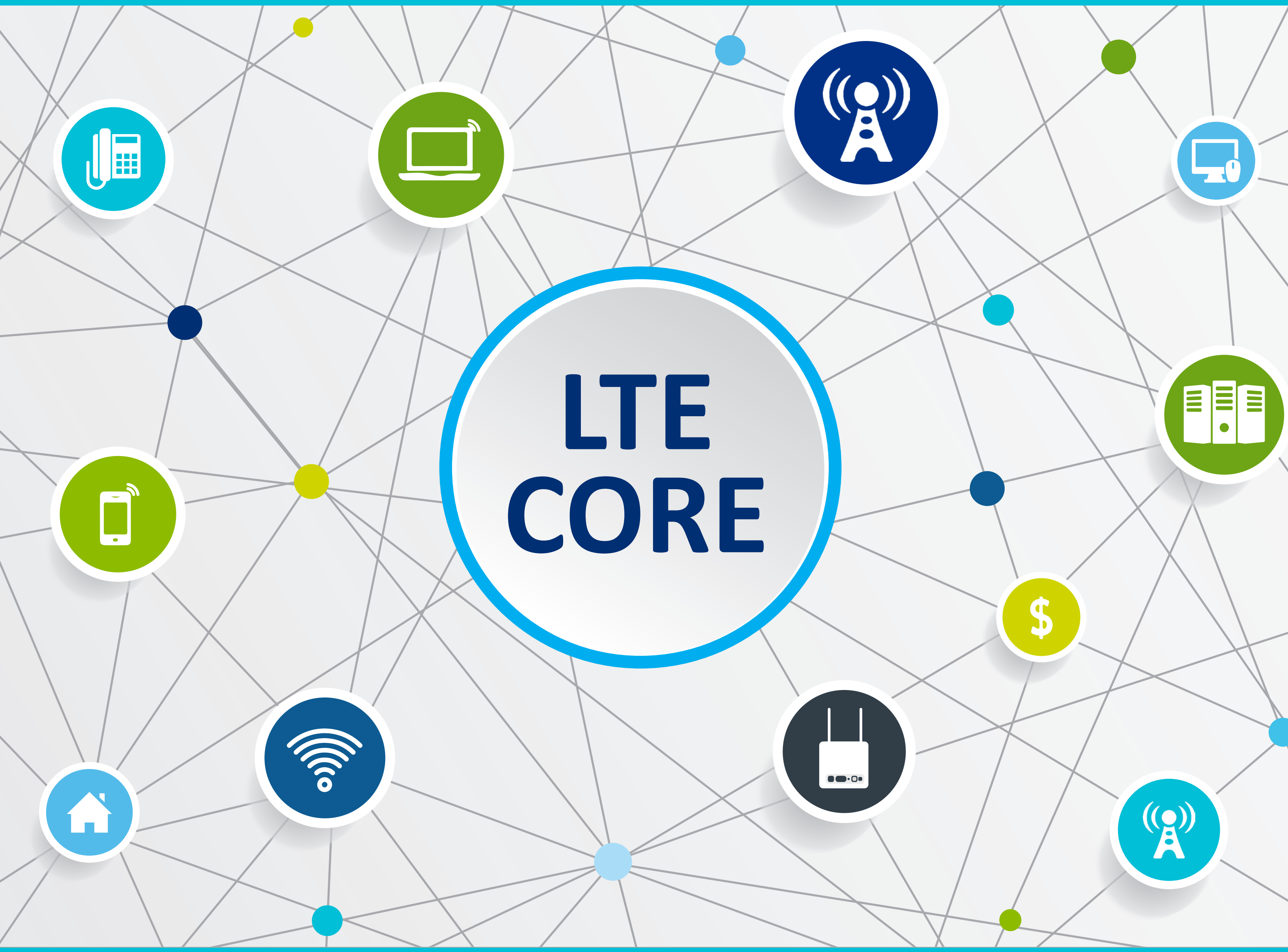

New Concepts for BWA Networks

by Mark Altshuller, CTO of Telrad Networks

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1. Introduction

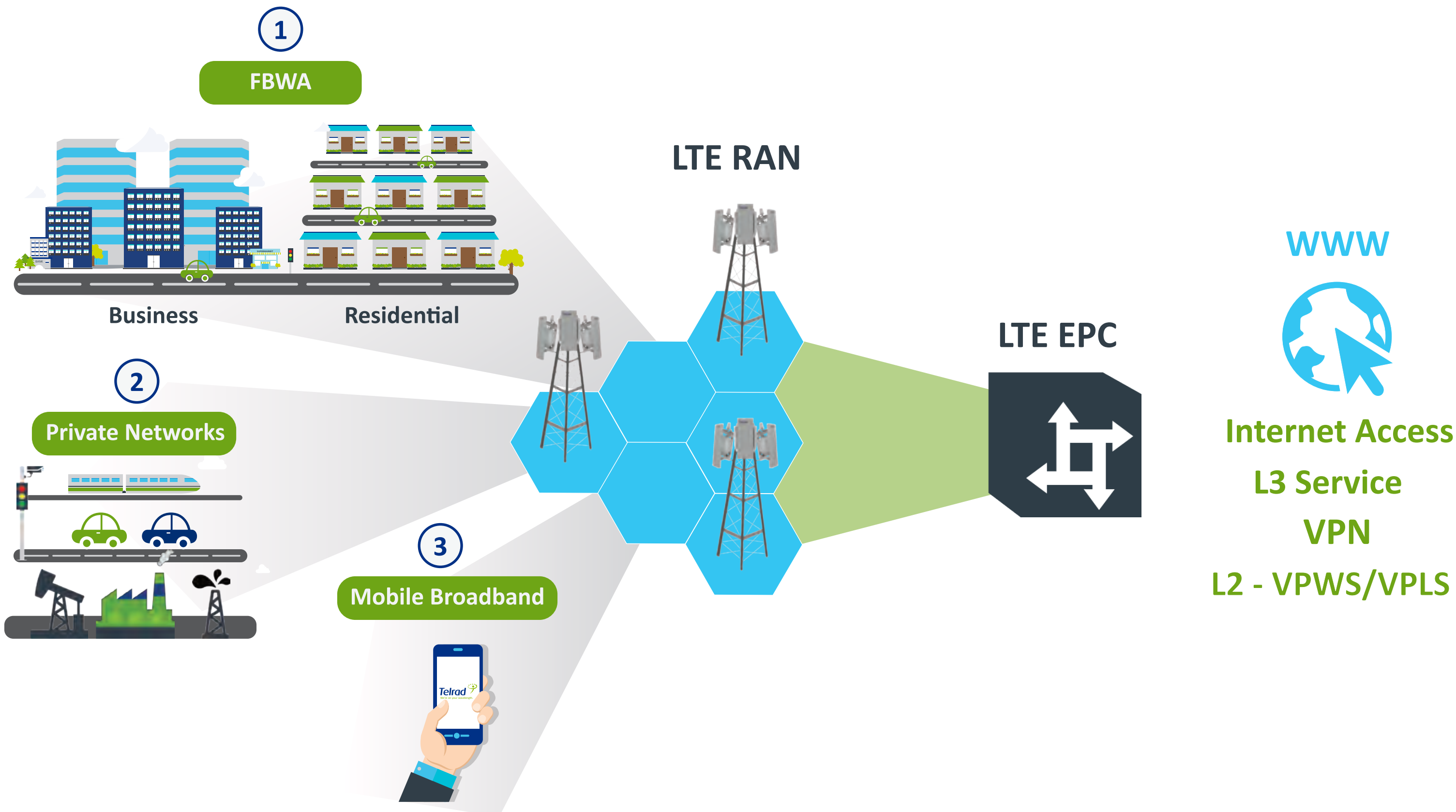
LTE (Long Term Evolution), as used by the mobile carrier market is reaching a widely used, somewhat mature state. The core network, known as the Evolved Packet Core (EPC), plays a significant role in the management of the LTE network. The EPC functions as the intelligence, policing and directing communication over the network. More importantly, in a typical LTE mobile application, it handles the mobility management and switching. LTE vendors offer EPC components that handle these large carrier networks, specifically to address their mobility requirements.

But what happens when an operator has deployed a fixed wireless LTE network? The goal of the network is to provide broadband service to customers at their homes and offices, in other words to fixed locations. They have no need for mobile functionality on their networks. Mobile EPC solutions become too pricey and complex with a core the functionality unsuited for a fixed application. The mobile EPCs, with hefty price tags, are cost-prohibitive for most small/medium Internet Service Providers such as those serving rural or developing markets. Moreover, they often cannot scale down to support networks with fewer than 10,000 subscribers.

This white paper explores the LTE core requirements of fixed Broadband Wireless Access (BWA) networks, discusses the current market offerings and suggests several considerations that need to be taken when selecting a proper EPC solution for fixed applications.

2. The role and requirements of LTE Core in BWA

LTE Core requirements in Broadband Wireless Access (BWA) networks are directly linked to the type of use-case scenario they support. Let's identify three use-case scenarios for such networks.



a. Fixed Broadband Wireless Access (FBWA)

FBWA is the most common scenario for BWA. FBWA is typically deployed by Operators as a standalone or as a Fiber-to-the-Home (FTTH) / DSL complementary last-mile infrastructure to provide broadband services to residential and/or business customers.
Historically FBWA deployments started with WiMAX technology in the early 2000s using 2.3, 2.5, 3.5 and 3.6 GHz FDD/TDD licensed spectrum. A couple years ago LTE TDD technology began penetrating into the FBWA space in parallel to the beginning of a WiMAX-to-LTE transition. It is expected that in the next 3-5 years most WiMAX networks will migrate to LTE TDD.

Since FBWA is emulating wireline connectivity to end users, it has equivalent **service requirements**, which impact the technology and business model when using LTE TDD technology.

Fixed Broadband Wireless Access (FBWA) Service Requirements:

- Most simple and basic is **IP connectivity** with a wireline-like user experience
- **Grade of Service (GOS)** and **Quality of Experience (QoE)** are much higher than in mobile networks, which result in maximized radio capacity utilizations.
- **High throughput** is required to meet growing traffic demand in-house for applications like IPTV, gaming and others
- **Layer 2 VPN** or **Carrier Ethernet** services for business and enterprise users
- Integration with existing OSS/BSS system using **Radius/AAA** as commonly used in other fixed broadband networks.
- **Differentiated QoS** for VoIP, video and enterprise usage
- **Gradual deployment** vs. mobile large areas deployments to launch the service in the specific location. This is one of the most important business model differences between FBWA and the typical Mobile/Cellular network deployment
- Lack of need for mobility creates the motivation to localize **traffic aggregation / termination** without having to bring the traffic to a central point over a costly transport network

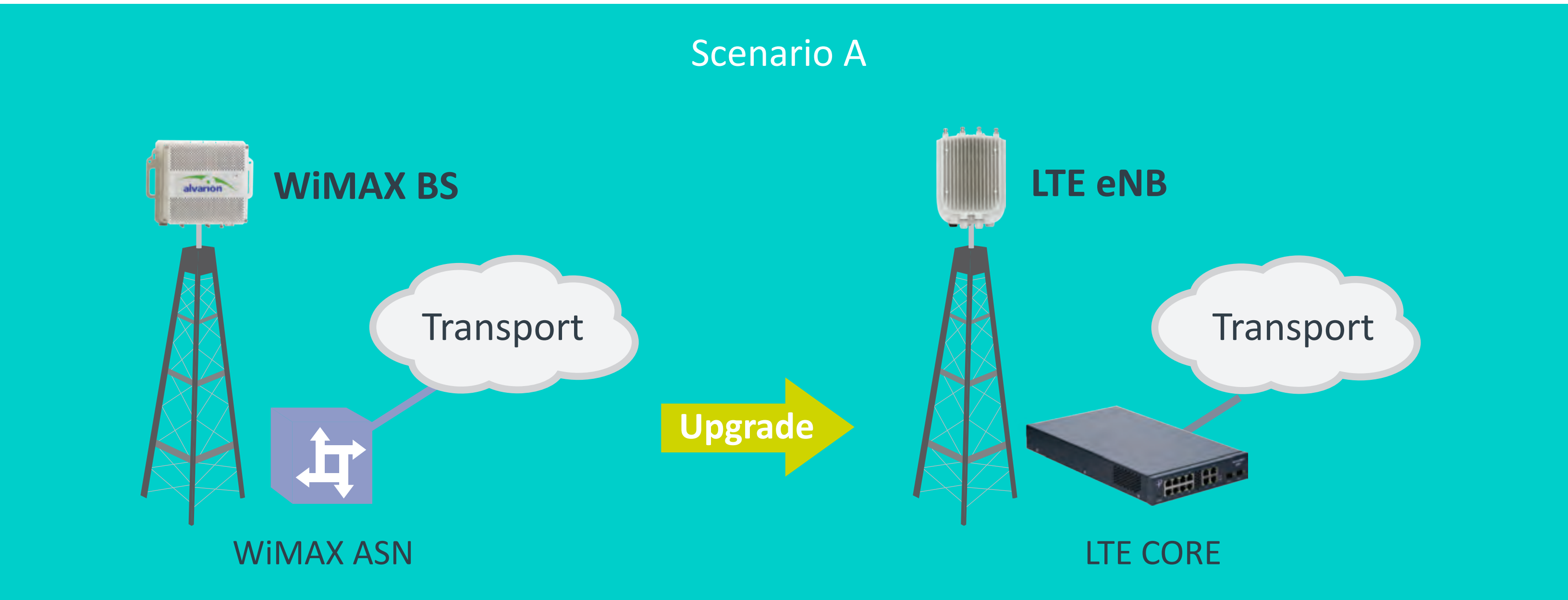
On top of the above common FBWA requirements, networks that are transitioning from WiMAX to LTE have additional challenges for minimizing CAPEX/OPEX and service interruption to their end-users. **The two main challenges when switching to LTE are:**

- **Service continuity** – enabling same end-to-end service transparency to the end user. Telrad identified this challenge when WiMAX was developed as a standard for either Mobile or Fixed uses. The networks need to consider the Internet Engineering Task Force (IETF) recommendations as a reference for networking capabilities (which is common practice in Fixed Networks), while using LTE, which is a 3GPP standard developed purely for Mobile industry.
- **Reducing migration costs -** Avoiding or minimizing infrastructure changes on-site, transport topology and OSS/BSS.

For transitioning networks, there are two common scenarios for the desired LTE Core and its existing WiMAX solution:

Scenario A: **Distributed Core Topology**

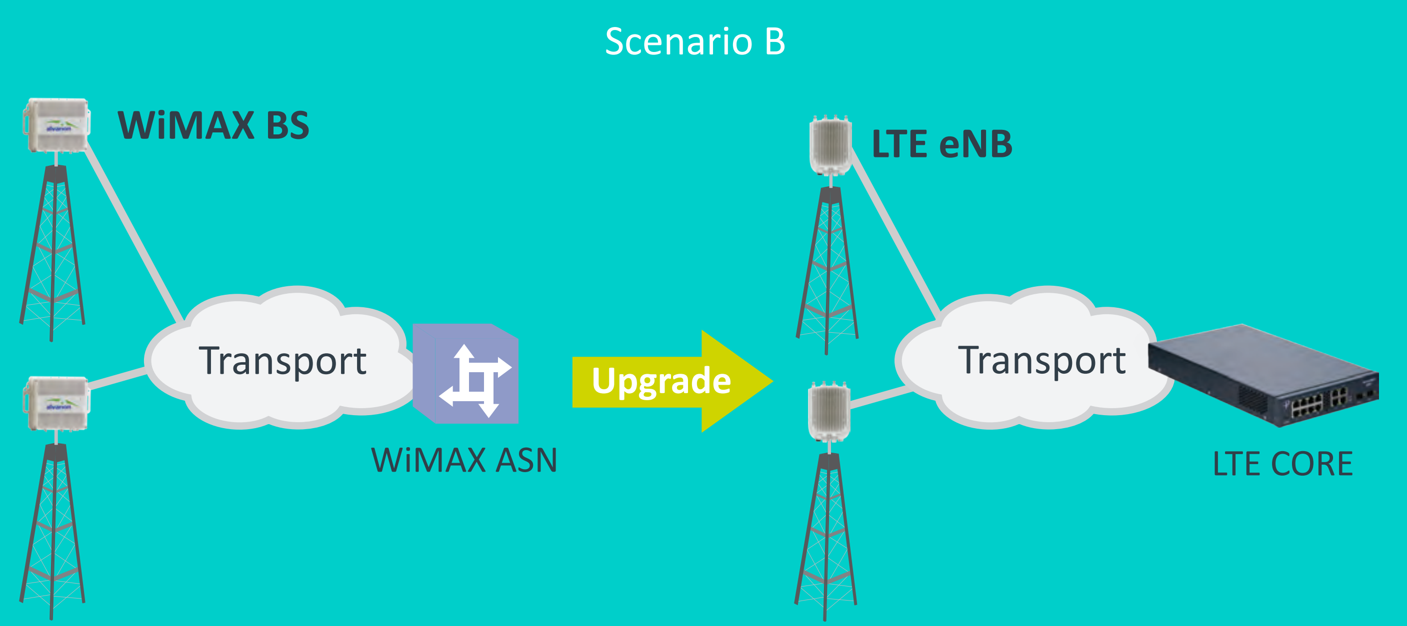
Scenario B: **Centralized Core Topology**



WiMAX to LTE Transition: Distributed Core Topology

WiMAX to LTE Transition Scenario A:

Cell-site ASN – many early deployments used ASN functionality integrated within the WiMAX Base Station site. This deployment topology has many advantages for pure fixed wireless service. Cell-site ASN obligated the operator to build the appropriate transport infrastructure, which allows interconnecting the user traffic from the cell-site directly with various nodes in the network. In this scenario it is likely when transitioning to LTE Core to keep a similar topology, meaning implementing LTE Core functionality on the cell-site level (as shown in the figure above).



WiMAX to LTE Transition: Centralized Core Topology

WiMAX to LTE Transition Scenario B:

Centralized ASN - Since WIMAX standard was developed for either mobile or fixed networks, many WIMAX deployments adopted a mobile Centralized ASN approach, where all the traffic in the cell site is directed toward/from a central location. In this scenario, a transition to Centralized LTE Core (EPC) it natural, however there is a gap in the ability to mirror connectivity to the back-end systems (OSS/BSS) and provide all the services which the WiMAX standard supports. Some examples are mentioned above, such as Layer 2 service, Radius/AAA interworking and more.

b. Private Broadband Wireless Access (PBWA)

PBWA networks can be referred to:

- **Governmental and Utility Networks** – can be deployment by municipalities, transport authorities, electricity companies and others for public safety, work force, IoT and other connectivity services used for non-commercial use.
- **Industrial Networks** – deployed by various industries (e.g. Oil & Gas and Mining) to enable similar needs as for Governmental/Utilities and more.

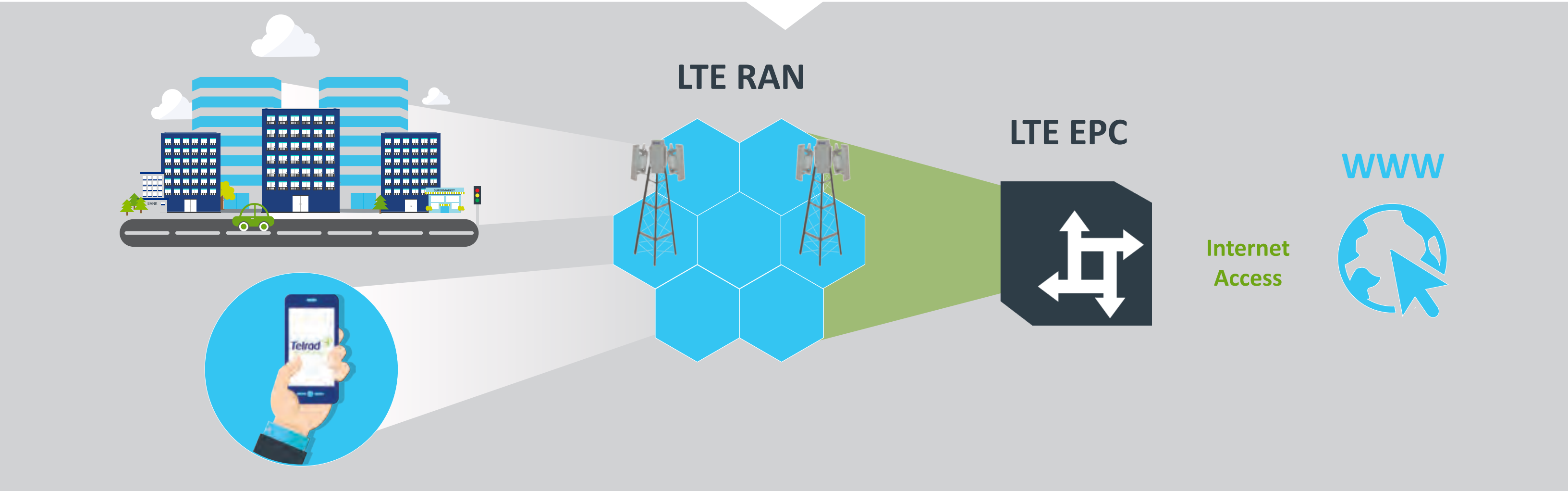
PBWA are not commercial networks and the technology life cycle is much longer than FBWA. Therefore, PBWA technology selection is less based on the worldwide trend, but more on the real fit of the technology to the needs from the business and service perspective. This is the reason why PBWA are open to using various technologies, among them WiMAX, WiFi, Mesh-WiFi, and proprietary. LTE is a newcomer to PBWA as this community identifies the value using LTE technology in private networks. In general, when looking at the PBWA requirements for LTE, there are many commonalities to the aforementioned FBWA.

However, some specific differences should be mentioned:

- **Mobility** – unlike in FBWA, mobility is an important need for private networks, since many require to serve connectivity with vehicles, buses, trains or other moving devices.
- **Localized** Core – many private networks use peer-to-peer traffic and therefore prefer to bring Core (traffic aggregation point) close to the base station. In this case the LTE EPC user plan (SGW/PGW) should serve limited number of base stations or even a single base station.
- **Uplink (UL) Traffic** – this ability, more important for private networks than for FBWA, enables applications like public safety and surveillance (e.g. connectivity to cameras) where the download traffic requirement is lower than the upload, which is the opposite of Internet traffic use.

c. Mobile Data Operator (newcomers)

This is a new segment. When deploying a BWA LTE TDD network on the mainstream LTE bands (like Band 40, 41, 42, 43) it opens an opportunity to provide data service utilizing the developing LTE device ecosystem. Today, most smartphones already support LTE Bands 40 and 41 and in the near future Bands 42 and 43 will be supported.



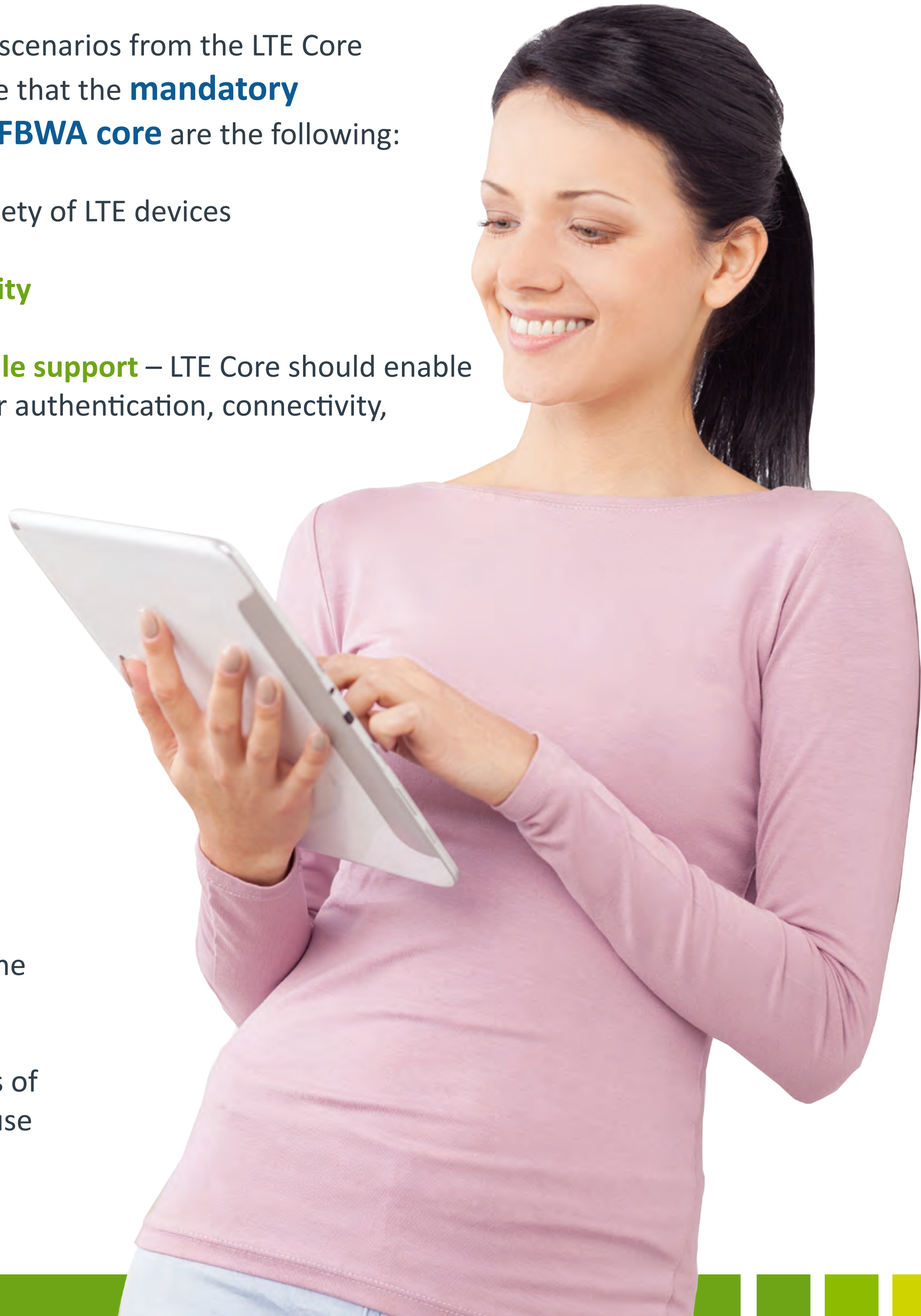
The operators, which used these bands for WiMAX networks or early LTE TDD deployments, are now seeing additional opportunities to provide mobile data service in the coverage areas. Several models are considered, such as MVNO, wholesale, roaming with different combinations with existing Mobile Network Operators (MNO) and Operators' backend systems.

This paper does not analyze this new model of operation, but it can certainly be considered as an evolution of the FBWA.

Typical requirements can be considered as a simple sub-set of the mobile LTE networks from a functionality and integration point of view. However, since it is a very new model, not all requirements are clear.

After analyzing the different scenarios from the LTE Core perspective, we can conclude that the **mandatory functionalities of an LTE FBWA core** are the following:

- **Interoperability** with a variety of LTE devices
- **IP connectivity with mobility**
- **Roaming/MVNO/Wholesale support** – LTE Core should enable various options for LTE user authentication, connectivity, billing.
- **Scalability** – since there is not always a massive service base from the beginning, operators exposed a desire to enable Centralized LTE Core (EPC), which can support a small number of users – saving on initial CAPEX.



This paper also shows how the Telrad LTE Core solution, BreezeWAY, meets the requirements and challenges of the above-mentioned BWA use cases.

3. LTE Core solutions – where is the market today?

Traditional LTE Core solutions are coming from the mobile world. In the mobile market most of the leading vendors have developed their own mobile core solution evolving from 2G and 3G (e.g. SGSN, GGSN, PDSN, HA). Since all core components in the mobile industry are located in central locations and serve a large number of users, all mobile core Gateways/Routers including the LTE core (EPC) are designed as large-scale products with high availability (e.g. fully redundant).

In addition, these LTE core (EPC) solutions support many mobile network functionality requirements (e.g. Inter-technology mobility with 3G), which are not required for BWA.

One of the major disadvantages of the traditional mobile core solution for BWA networks is the initial cost of the LTE EPC, whose starting point is often over $100K USD (for basic EPC functionality) and the initial cost continues to grow when adding PCRF (for QoS), HSS and other OSS/BSS requirements. Therefore, for many BWA deployments, which start with a small, perhaps a few-thousands subscriber region, the initial investment of $100K USD for an LTE EPC is extreme and often not viable.

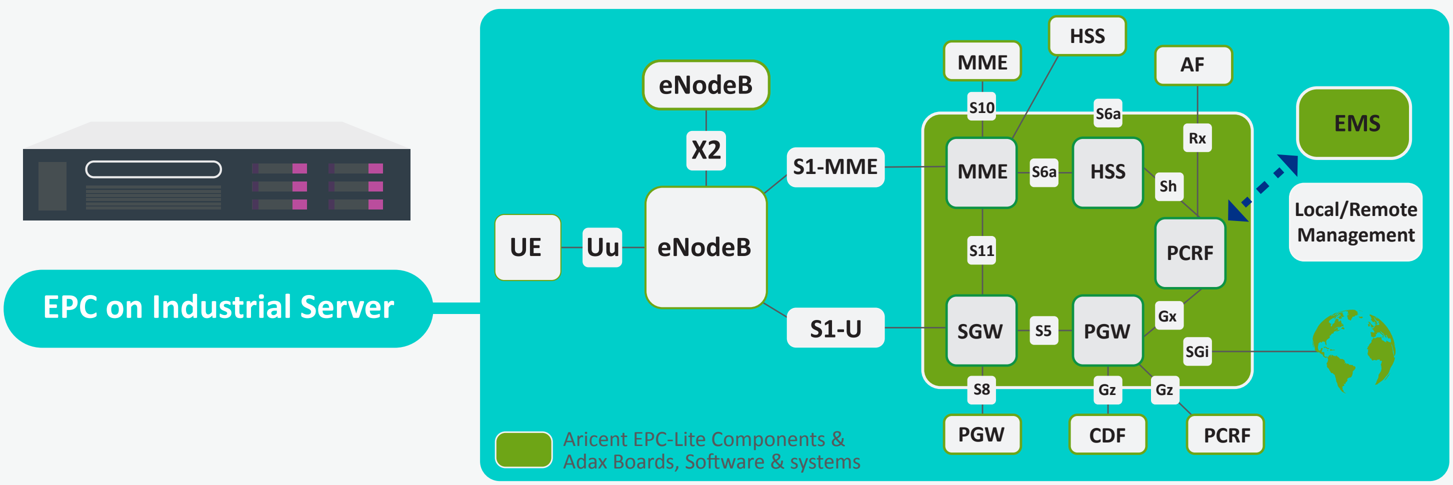
Recently this problem was recognized as a business model bottleneck for BWA and the market started proposing different EPC solutions and models to overcome the high initial EPC cost issue. Some EPC options that currently exist in the market are:

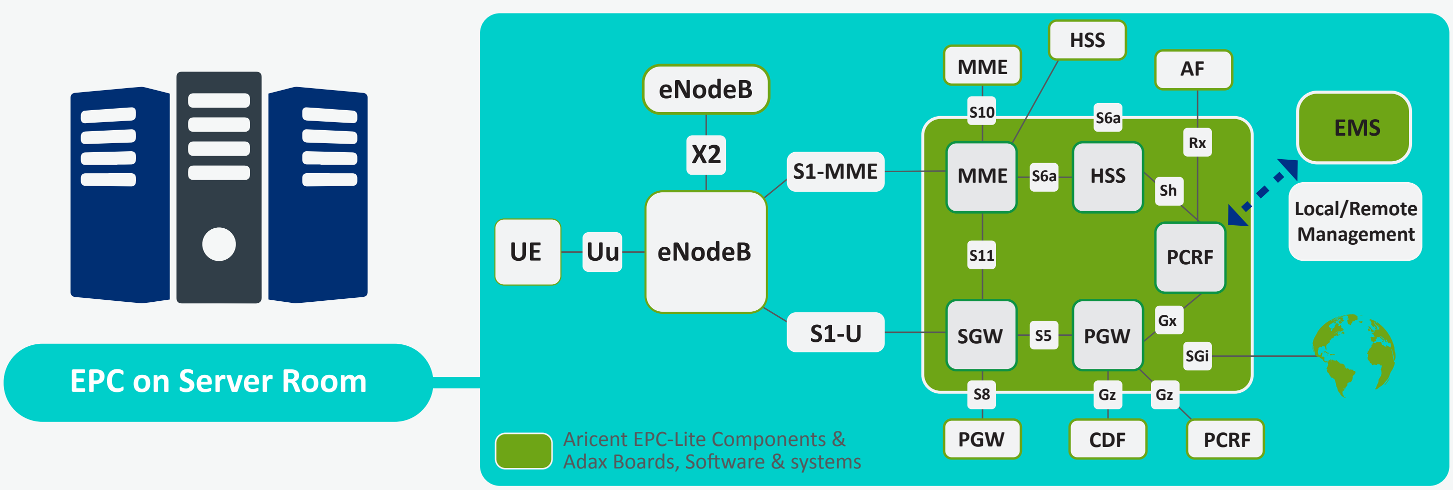
- **Monthly EPC subscription fee** – this model is offered by some large vendors and it is a creative way to propose payment terms. In practice the same high scale EPC is supplied, but instead of paying the initial cost, the operator is required to pay monthly license fee per subscriber. In some cases the monthly fee is ~$1 USD per user, meaning that the cost per user in one year is equal to $12. This can turn out to be a very costly solution as the network grows.

- **Cloud EPC** – this is a mixture of payment model and technology architecture. It is not always clear what is the real solution behind the "cloud" offering. Additionally, a cloud-based option creates security vulnerabilities, putting operator and user data at risk. Telrad investigated some "Cloud-EPC" proposals and found the following two types:

"Cloud-EPC" proposals types:

- o Same **high scale EPC installed in the central location.** The company (vendor) offers the operator a sharing model, where the **EPC is used by multiple BWA operators.** One of the major disadvantages of this approach is the need to bring the user traffic to a central location, which is not always justifiable for BWA.
- o **Software based EPC** – over the last two years some new vendors have begun to offer EPC solutions based on software stacks available in the market and install them on standard industrial servers. With relatively small R&D investment it delivers a lower scale EPC solution. The major disadvantage of this approach is that these solutions are not mature enough to scale up in performance and in practice only work well in a lab environment or in very small-scale networks. In addition, the major cost of the EPC is the cost of the industrial server ($10-20K USD for small network) with some additional EPC software licensing on top. This model presents a danger for operators, as it does not provide the EPC vendor enough justification to sustain R&D resources for long-term support and roadmap development. Also it makes high scale EPC extremely costly due to the industrial server prices that accumulate as the network grows.





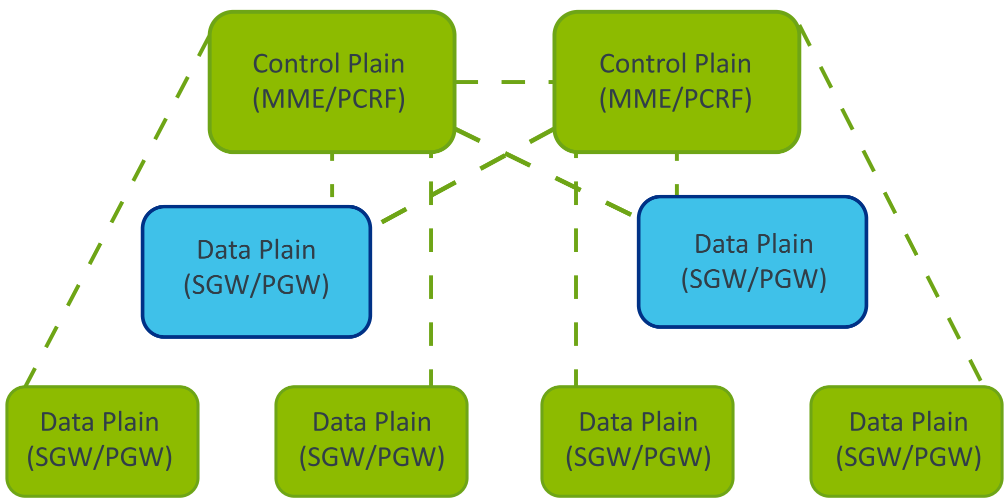
The Telrad BreezeWAY EPC portfolio addresses all of the major disadvantages of the different EPC solutions for BWA networks described above. The next subject explains how the Telrad BreezeWAY unique distributed architecture overcomes all these issues, delivering the lowest cost, high performance and most scalable EPC solution in the market.

4. BreezeWAY LTE Core – how it fits BWA requirements

The Telrad R&D team invented the mobile core distributed architecture technology used during the WiMAX period. In the early 2000s this team invented and developed a distributed WiMAX ASN core solution, and thousands of these ASN GWs were deployed around the globe over the last 10 years. Building on this success and experience, in 2013, Telrad started developing the BreezeWAY LTE core platform.

The following innovative architecture and product concepts are part of the BreezeWAY LTE core:

- **Partitioning between user/data and control planes** – for this architecture, the R&D team registered patents which were approved. In fact, this partitioning is the early stage to building the most optimized Virtual-EPC solution. It enables the distribution of user traffic anchoring points in the most optimal locations of the operator's transport network and gives a lot of flexibility in creating geographical redundancy, load balancing, and scalability of the core networking solution (see the conceptual figure below)



- **User/Data plane hardware acceleration** – Telrad's experience shows that running LTE/WIMAX core traffic requires a dedicated and powerful network processing. In BWA, even more than in mobile networks, the core GW (e.g. EPC) requires deep classification capabilities to provide multiple options and flexibilities for user traffic forwarding, QoS policies and other important functionalities. All SW-based EPCs are running on general-purpose servers without optimized HW acceleration architecture and therefore require costly servers with high processor power to bear the EPC user traffic performance. On the other hand, Telrad's scalable and high performance BreezeWAY HW acceleration architecture reduces the HW cost by more than 10 times compared to server-based typical SW-EPC solutions. This Telrad assessment is based on the following lab testing results:

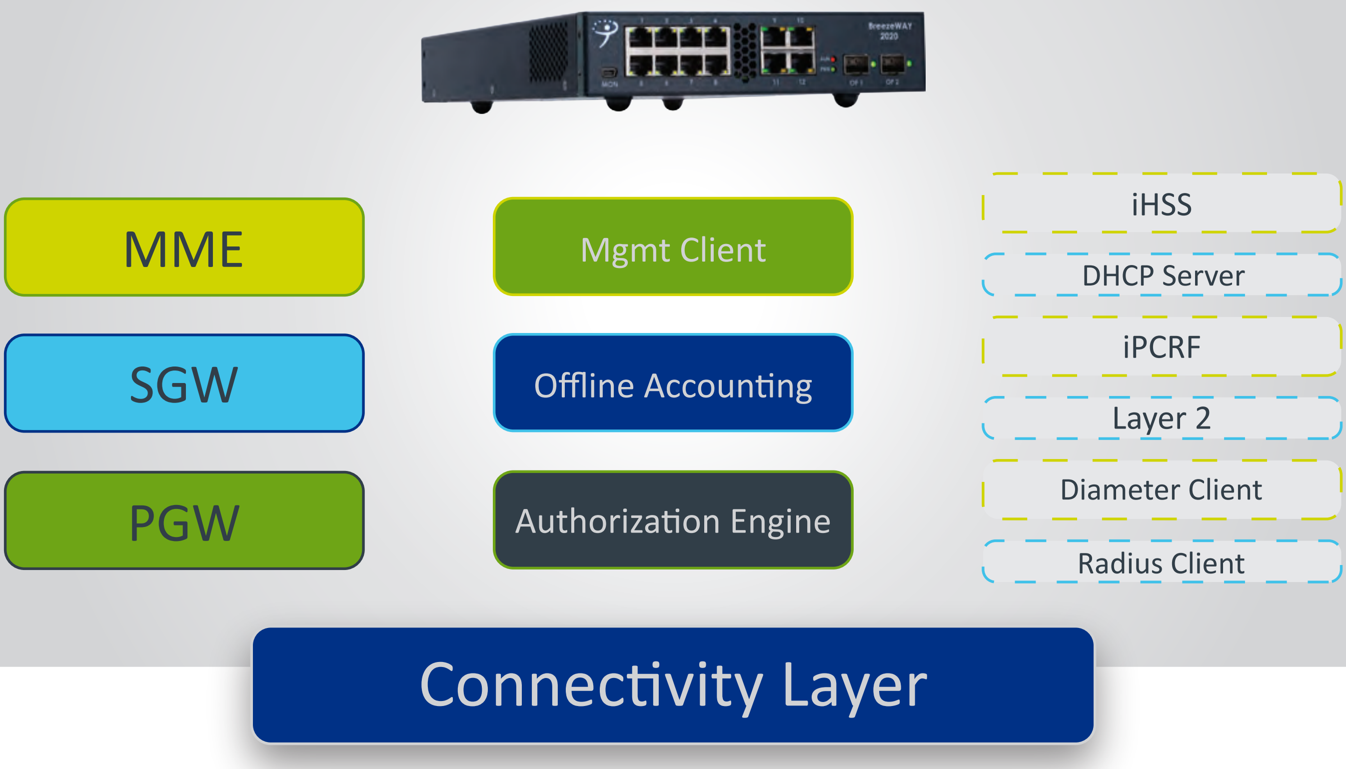
Telrad installed an open EPC stack on a typical industrial server with 4 core CPU @ 2.5GHz and 8 GB RAM (medium range server). With large packet size (1000 bytes) traffic, the maximum achieved UDP throughput was **730 Mbps**. The market price for such a server (not including EPC SW licensing) is around $2-3K USD. In comparison, the Telrad BreezeWAY platform supports **8 Gbps** (even for short packet sizes) for a similar price to the server including SW licensing, which is equivalent to more than 10 medium range servers in performance.

- **Exclusive general-purpose and open architecture** – previously, GW and router products used proprietary network processors. This created a dependency and lack of flexibility for mid-sized developer companies like Telrad. In the BreezeWAY architecture, Telrad developed its EPC HW acceleration on general-purpose field-programmable gate array (FPGA) components using exclusive technology. The result of this architecture solution is the lack of dependency on any proprietary network processor manufacturer, with the flexibility to develop various EPC core scales (from small to large) at very aggressive cost structure integrated in a small packaging. The BreezeWAY platform uses a well-defined application program interface (API) between the control and user planes, which is aligned with the latest NFV (Network Function Virtualization) architecture. The BreezeWAY EPC has evolved into a truly unique, one-of-a-kind in the market, distributed, HW-accelerated, virtual EPC solution.

- **Room for many features beyond basic EPC** – the combination of powerful HW acceleration architecture with the control plane partitioning creates a lot of performance room to add additional capabilities to the BreezeWAY platform basic EPC functionality, requiring the addition of software only. In 2015, Telrad developed **unique SW features** to add to BreezeWAY for the BWA market:

    - **Layer-2 SW engine** – using HW acceleration architecture, BreezeWAY supports full Layer-2 functionality to provide L2VPN services enabling VPLS and VPWS topologies. This is the **first solution in the market which enables Carrier Ethernet services over LTE,** embedded within the LTE EPC.

    - **iHSS and iPCRF** – these SW packages integrate HSS and PCRF capabilities into the EPC at much lower cost than their equivalent expensive external HSS and PCRF products in the market. The all-integrated iHSS & iPCRF within the BreezeWAY core makes the system more flexible and simple for operators to control per-user policies.



As per the illustration above, Telrad's EPC's architecture fundamentals create the most optimized, scalable LTE core solution for BWA networks enabling a combination of fixed and mobile services.

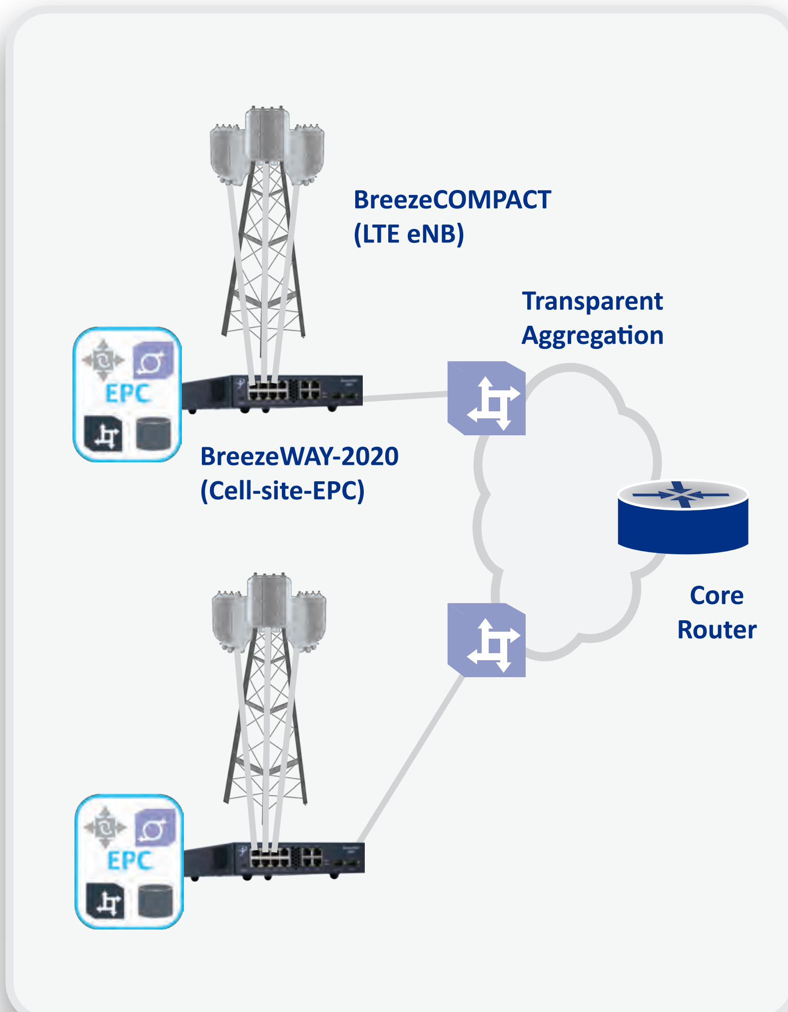
5. BreezeWAY products and deployment configurations

Today, Telrad has three BreezeWAY architecture products:

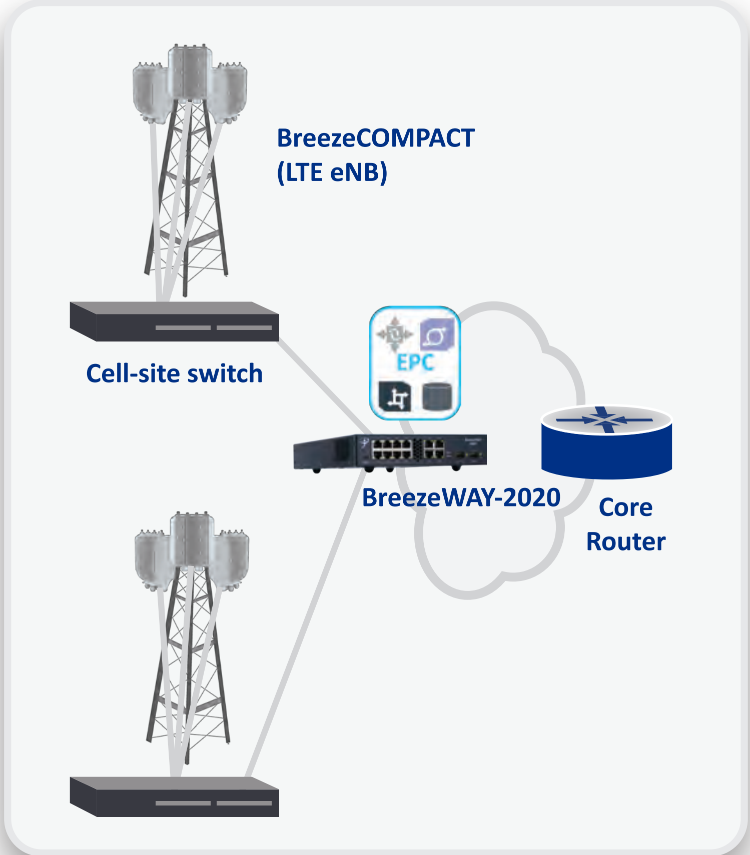
BreezeWAY-2020 – this is a half-shelf, 1U box, supporting a maximum of 10,000 connected LTE UEs and 8 Gbps traffic. Powerful HW acceleration backplane of 80 Gbps enables great performance for all networking features even beyond the standard EPC as mentioned above. BreezeWAY-2020 is a very scalable EPC solution, which enables the lowest configuration starting from 150 UEs and scaling up to support million of UEs. The pictures below show the typical BreezeWAY-2020 topologies.

- **BreezeWAY-2020 cell-site EPC** – with a minimum of 150 UEs licensed, BreezeWAY 2020 provides a very attractive solution to be installed in the cell site. The BreezeWAY-2020's twelve LAN ports can be used as combination of on-site switching and aggregation of the BS equipment and local EPC functions with additional features, like Layer 2, iHSS, and iPCRF. The attractiveness of this solution for a fixed BWA system is clear, since it terminates all user traffic locally on the site and does NOT mandatorily bring the traffic to the central location.

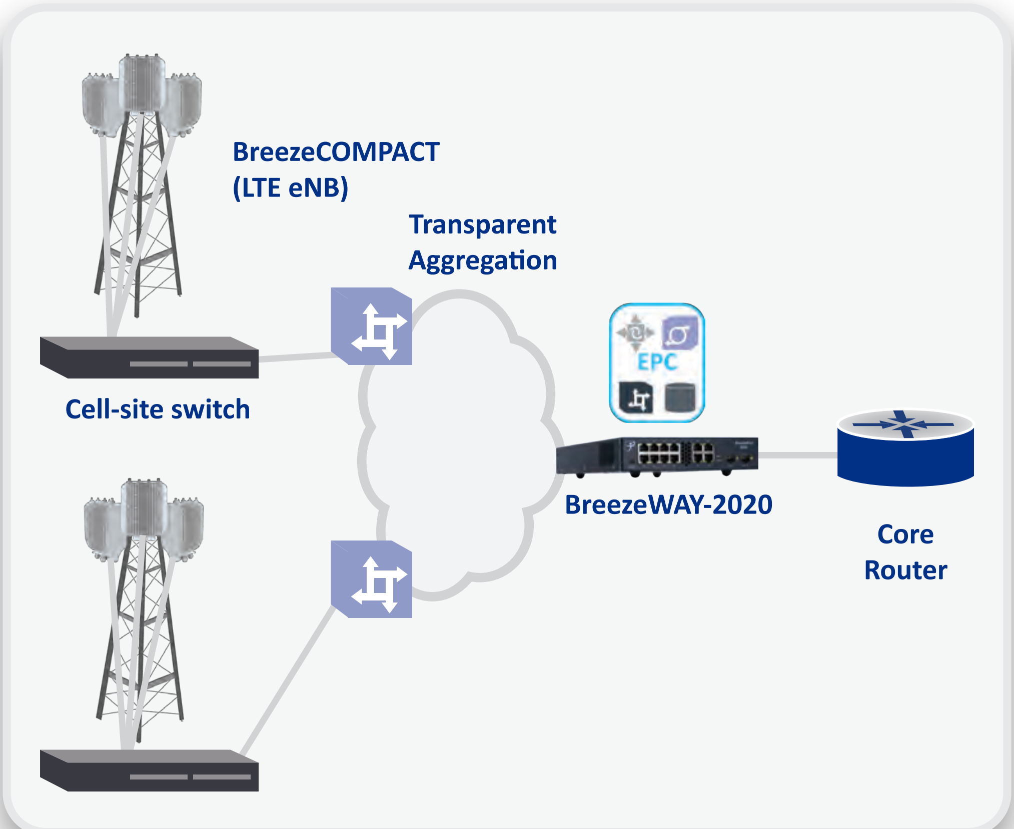
  The system is more resilient for non-carrier-grade backhauling (e.g. satellite, unlicensed band) than standard central EPC topology, where the S1 control plane (eNB-EPC) interface is Stream Control Transmission Protocol (SCTP) based and therefore very sensitive to any backhauling/transport disruption.



- **BreezeWAY-2020 local aggregation EPC** – the difference between the cell-site and this topology is that, in this case, the BreezeWAY-2020 uses its scalability to locally aggregate a few cell-sites. In this cell-site topology, more efficient localized mobility is possible, adding great value.



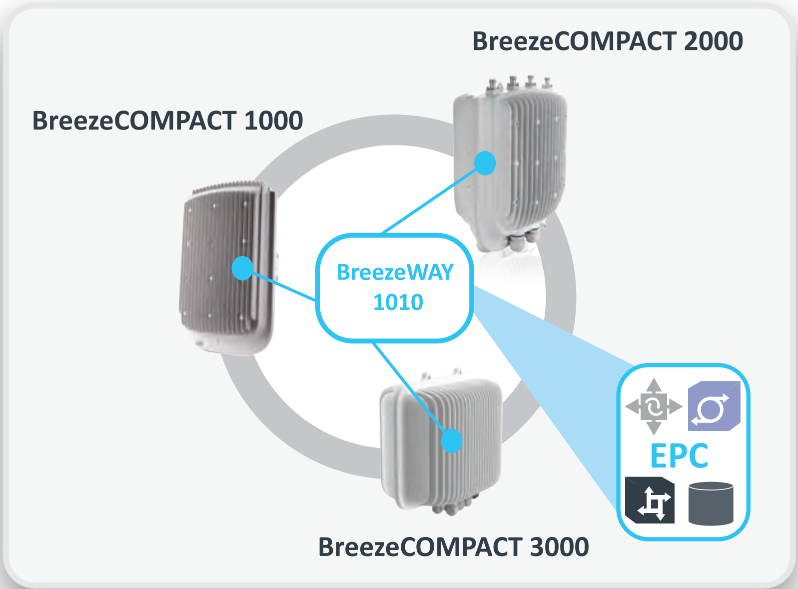
- **BreezeWAY-2020 Central EPC** – the BreezeWAY-2020 distributed architecture is a very advanced solution for Centralized EPC compared to any EPC solution currently on the market. BreezeWAY-2020 EPC supports advanced capabilities of load balancing, m+n redundancy and clustering, delivering an EPC solution with extreme performance and scalability. With Telrad's BreezeWAY-2020 the operator may start a deployment with 1000 UEs and grow in steps of 500 UEs while enjoying a significantly lower price, for any network size, than any other solution on the market.

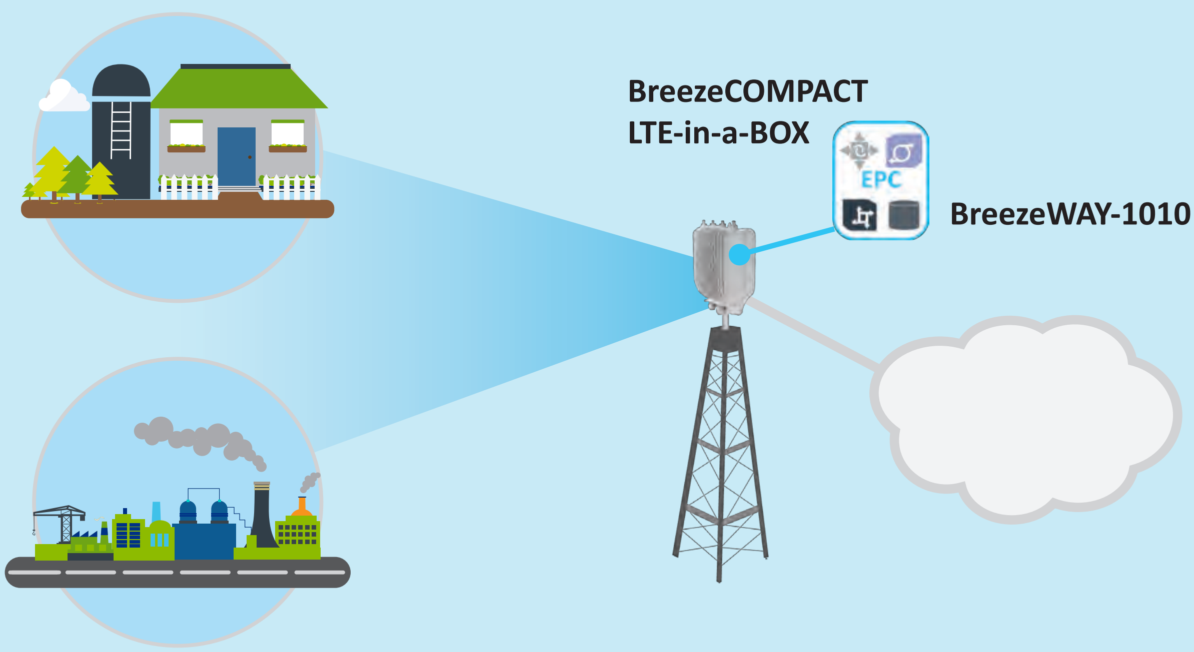


BreezeWAY-1010 – this is a scaled-down version of BreezeWAY-2020. Telrad developed BreezeWAY-1010 and launched it at the Mobile Word Congress 2016 show, as the smallest EPC in the world.

The BreezeWAY-1010 is now embedded in Telrad's BreezeCOMPACT eNB product, creating a unique **LTE-in-a-BOX** solution. The BreezeWAY-1010 has a great scalability starting at 50 UEs and grows in steps of 50 UEs using SW licensing up to a maximum of 500 UEs.

With BreezeWAY-1010, the LTE operator may install a full-outdoor LTE network on the tower. This is a very cost-effective solution to provide connectivity in very rural or remote areas and various industrial deployments, where the operator does not want to invest in costly cell site cabinets and other infrastructure.

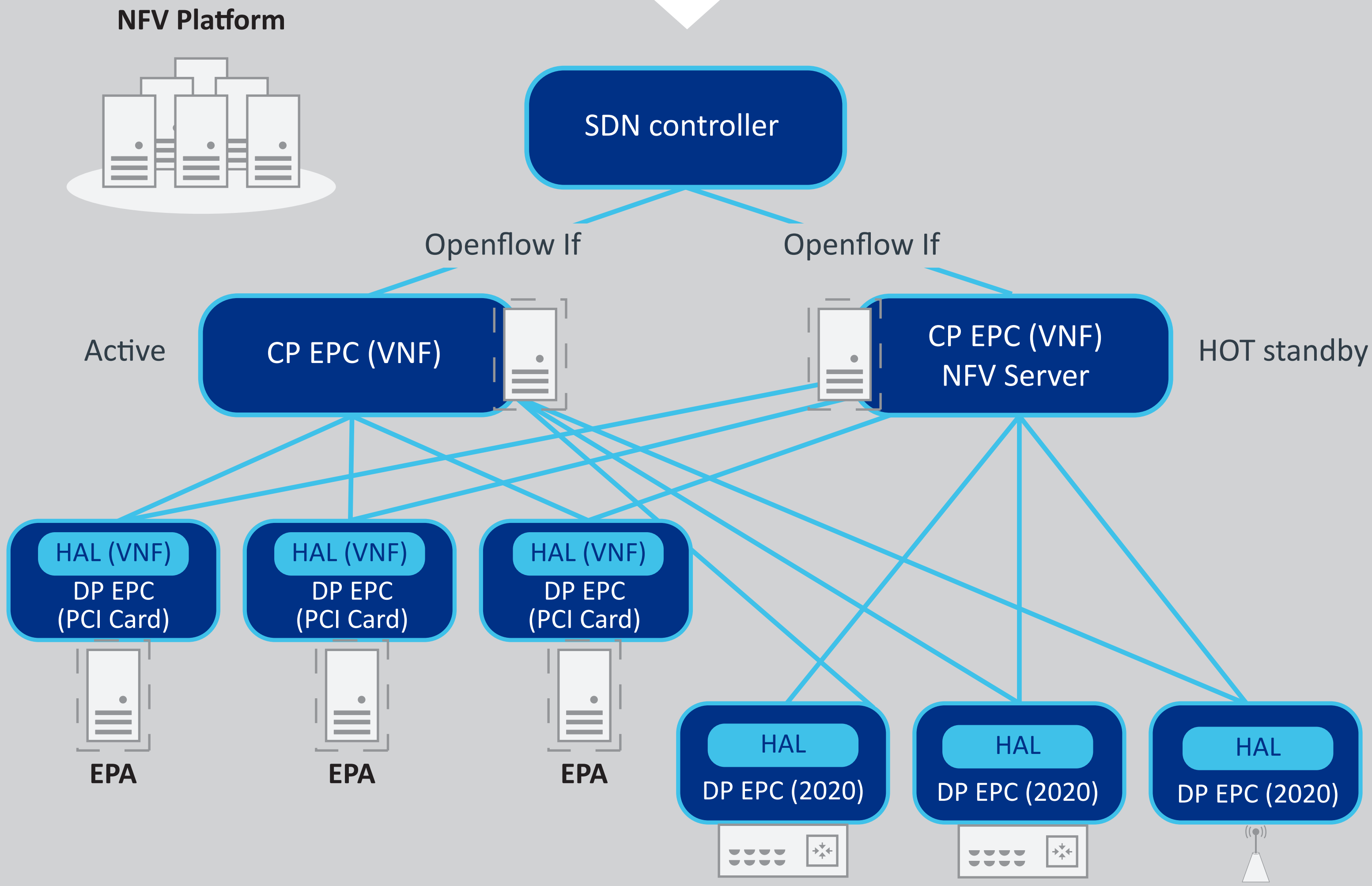




Since BreezeWAY-1010 and BreezeWAY-2020 both share the same platform, they share the same feature set, SW versions, NMS provisioning, and subscriber management. Therefore an operator may combine both BreezeWAY products in the same network. Such a combination creates powerful network engineering flexibility to place an EPC node in any location.

BreezeWAY-3030 – this is Telrad's BreezeWAY platform evolution to a Virtualized and Distributed EPC. While other Virtual EPCs are running on the server environment, BreezeWAY-3030 is unique in its distributed architecture combined with virtual network function (VNF) based architecture. The figure below shows the conceptual diagram of BreezeWAY-3030, which diagrams how the BreezeWAY-1010 & 2020 are integrated within the BreezeWAY-3030 concept. BreezeWAY-3030 utilizes the major values of the BreezeWAY VNF-based platform separating control & data planes and runs the data plane over a general-purpose HW acceleration packet-processing module.

In practice, by deploying the BreezeWAY-1010 or 2020, operators have a natural evolution to the Virtualized-EPC BreezeWAY-3030 without changing the deployed EPC nodes and avoiding any transport network restructuring.



6. Summary

Telrad's BreezeWAY LTE core solution is the most optimized solution for the BWA market in a variety of deployment scenarios. The BreezeWAY portfolio brings operators:

- The **best price-performance ratio** in the market with a pay-as-you-grow pricing structure.
- **Lowest scalable entry-point** from 50 UEs for BreezeWAY-1010 and 1000 UEs for BreezeWAY-2020.
- **Rich feature set** for the BWA market, beyond the standard EPC functionality, with added functionalities like Layer 2, iHSS, and iPCRF.
- **High performance and carrier-class reliability** supporting m+n redundancy and load balancing.
- **Evolution to BreezeWAY-3030** – unique distributed virtual EPC solution.