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IEEE 802® NETWORKS FOR VERTICAL APPLICATIONS

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IEEE 802® NETWORKS FOR VERTICAL APPLICATIONS

1. BACKGROUND AND INTRODUCTION

IEEE 802® technologies are used for a wide variety of applications and markets. Despite the widespread usage and overwhelming adoption of PHY and Link layer technologies for all kinds of information and communication solutions, a common perception of the value and differentiation of the IEEE 802 architecture in the context of vertical markets is not established. There are no clear views about why IEEE 802 would be better suited to deployments in the communication infrastructure of private enterprise, industry, and the individual user, and how IEEE 802 compares to network architectures oriented toward service providers.

In the first stance, it could be agreed that the IEEE 802 architecture enables networks that are like IEEE 802.3 Ethernet—well understood, mature, predictable, offering a “cleaner” integration of disparate technologies under the common architecture and addressing.

This white paper aims to collect and spell out commonalities of IEEE 802 technologies and set the scene in relation to other well-known communication standards of similar behavior.

2. REQUIREMENTS OF VERTICAL APPLICATIONS

This section defines the characteristics of vertical applications that usually integrate various systems, including network connectivity, in order to perform specific tasks or enable use cases for their industry.

In the context of this white paper, “vertical applications” refers to networks that serve specific use cases in specific market segments. The network is used by the entity to enable its business processes. This is in contrast to an access network, where the network services are the product.

Vertical markets involve the following specific usage models:

- Industrial automation
- Building automation
- Smart cities
- Smart grid/utility
- Automotive/transportation
- Agriculture
- Connected supply chain
- Critical infrastructure protection and control
- Wide area gaming (including AR/VR)

There are other ways of looking at “vertical.” Vertical integration is really a competition/antitrust term rather than a technical term. In that context, it describes a technical situation in that some set of functionalities that may be provided by the same company could actually in practice also be provided by different companies. So, for instance, “5G” is “vertically integrated” because it actually assumes in its technical specifications that a single commercial provider will be responsible for a whole range of different features that are not really separable. In that sense, IEEE 802 technologies are not “vertically integrated” because they can be deployed by different operators of completely different networks (e.g., one leverages wired connections, while others are based on wireless connectivity). Nevertheless, IEEE 802 plays a role in vertical integration by providing the plain connectivity layer, e.g., IEEE 802.11 in IEEE 1609 vehicle-to-vehicle communications, or IEEE 802.15.4 in the SEP.

Vertical markets often require highly engineered networks to guarantee the quality of the required communication services. Quite often, vertical markets follow extended lifecycles; the vertical network is expected to remain in service for a longer time than a service-provider network. Vertical markets may have different cost models compared with usual public communication networks where some are opex averse and others are more capex averse.

3. ECONOMIC ASPECTS FOR VERTICAL APPLICATION NETWORKS

IEEE 802-based networks are usually aimed to “enable creating/delivering a product” instead of “the network is the product” defined by an open standard:

- An IEEE 802 network is deployed in vertical markets, where the network is owned and operated by the user of the services.
- There are also other models than subscriptions that provide ancillary economic value.
 - An economy of scale can be accomplished by creating a network that can be leveraged by multiple entities. This is similar to cloud thinking—the model of sharing the infrastructure (network) without needing them to be independently installed and managed. It is a similar concept to a data center, just providing computing resources but not dealing with installing and running software for all the services needed.
 - The trend toward more virtualization is a strength of IEEE 802 because it allows the network to be better prepared for that virtualization. It provides a clean separation between the infrastructure and the service running on the infrastructure. In the IEEE 802 case, this is the layer 2 to layer 3 boundary.
 - The IEEE 802.3 Ethernet transport is the most well-understood transport in existence. This is analogous to the X86 computer architecture that became the basis for the computing resources of data centers.
- IEEE 802 and unlicensed spectrum enable faster innovation.
 - Many of the breakthrough innovations were not as planned.
 - The story of why IEEE 802 complements everything else, and everything else (alone) is not sufficient.
- The IoT is built around many specialized niches. The challenge is meeting their diverse requirements. No single standard can address all of them well. IEEE 802 provides multiple standards to address multiple IoT applications (see Appendix A).
- The model for network management requires special attention when the owner/operator of the network may have less expertise in network management. Guidance is desired on how to manage and operate a private network. Usually, this is simpler because the IEEE 802 network is simpler (compared to 3GPP, for example), but the documentation is often not really mature or available. Yang modeling describes the interface, but more knowledge is needed to understand how to use the network management data available through the interface.

3.1. MODULARITY AND INTERCHANGEABILITY, COMPETITION ECONOMICS

A user of a vertical application may want to be able to replace parts of their vertical application network with a better, newer product when one arrives (for instance, installing a new AP when a better one is available from a different vendor). IEEE 802 products lend themselves to this form of user-empowered modularity.

Building blocks with smaller functional content and broader variation offer this flexibility to the vertical application. 3GPP 5G (or cellular networks in general) does not have this modular feature. Although many UE vendors can be certified to the specifications, it is much harder for the network owner to mix multiple vendors in the RAN and core of the network.

3.2. POSSIBILITY OF SMALL BUSINESS ENTITIES DEPLOYING SMALL-SCALE NETWORKS

It would be possible for a small utility or municipality with only a few employees to set up a reasonably secure Wi-Fi network at their workplace, perhaps with temporary help from a consultant if they were making sure it was really secure. However, they would find it much more difficult to acquire a municipal spectrum license for LTE technologies and install, configure, and maintain a 3GPP private network infrastructure.

IEEE 802 also enables a greater degree of scalability. A network that starts small can easily be scaled to more complexity and users as the business grows. A 3GPP access network is designed from the start for a large scale and is more difficult to apply at a small scale.

4. KEY ASPECTS OF THE IEEE 802 TECHNOLOGIES FOR VERTICAL APPLICATIONS

4.1. LAYERING

- IEEE 802 is a transport network.
- IEEE 802 is layer 2.

- IEEE 802 provides direct and simultaneous support of IPv4 and IPv6 or pure layer-2 protocols.
- IEEE 802 offers trade-offs and optimizations between flexibility (L2) and scalability (L3).

4.2. ROUTING AND BRIDGING

- IEEE 802 enables networks to scale with routing and bridging.
- IEEE 802 supports layer-3 protocols such as IP, which enables routing to enable IEEE 802 networks to expand to a higher scale.
- IEEE 802 networks can be built on a smaller scale to provide more flexibility.
- The smaller scale provides an opportunity for real-time.
- IEEE 802 standards can emulate a point-to-point network over a wireless point-to-multipoint network to enable bridging over the wireless link.
- IEEE 802 can support multiple different L3 and above protocol suites.
- IEEE 802 can also offer L2 routing when appropriate (e.g., IEEE 802.15.10).
 - Note: This is not an alternative to L3 routing, but used to address a different problem.

4.3. MANAGEMENT AND CONTROL

- IEEE 802 does not provide as many means of control for a specific end device and its traffic on a path.
- There are some management facilities with some standards.
- It is easier for IEEE 802 to support an “unmanaged” network, such as consumer Wi-Fi.
- IEEE 802 provides local networks that may be (but do not have to be) connected to the internet or other networks.
- Public operator networks are focused on services for single devices, while IEEE 802 networks support and include multiple devices (networks of networks)—devices can communicate with each other as well as with other networks.

5. COMMON NETWORK MODEL FOR VERTICAL APPLICATION NETWORKS

A common foundation of the network architecture for a variety of vertical applications is provided by IEEE Std 802.1CF™-2019, IEEE Recommended Practice for Network Reference Model and Functional Description of IEEE 802 Access Network.

All communication networks providing the means to connect various communication endpoints (terminals) to the same or different information servers over a shared infrastructure follow the same architectural principles. IEEE 802 technologies support the realization of an access network, which establishes the shared infrastructure, allowing the management of the connections of a wide variety of terminals through wired or wireless interfaces to their communication peers, either through bridging in the local area, or through routing by an access router in more widespread networks.

5.1. NETWORK REFERENCE MODEL

Figure 1 shows the mapping of the IEEE 802 NRM to usual communication network topologies. The core of the NRM is the access network that connects terminally either directly through bridging or forward traffic to the access router when the communication peer is behind the same Layer 2 domain. Various control entities support the access network to provide secured and managed connectivity.