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TECHNICAL SPECIFICATION

Access, Terminals, Transmission and Multiplexing (ATTM);
Sustainable Digital Multiservice Cities;
Broadband Deployment and Energy Management;
Part 2: Multiservice Networking Infrastructure
and Associated Street Furniture;
Sub-part 1: General requirements

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

The present document is part 2, sub-part 1 of a multi-part deliverable covering Sustainable Digital Multiservice Cities (SDMC). Full details of the entire series can be found in part 1 [i.1].

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Executive summary

The main objectives of cities are to improve citizens' lives, local economy dynamics and to attract new residents and enterprises to establish locally. Strong evolutions in the fixed and mobile Internet connectivity have impacted the expectations and behaviours of the people and the enterprises they are working in.

Digital services have become an important part of the daily life, crossing many activities within the day. From personalized morning news, through latest updates on the transportation schedule (bus, train, road traffic), the operations at work or schools even up to shopping at the supermarket; the way people behave has greatly evolved. This digital revolution has also entered the area of services and operations delivered by public services such as the city. To adopt this evolution, the Information Communication Technology (ICT) platforms of the city services should be rethought and changed from the silo strategy to an integrated approach. To achieve this goal, the ICT of the city should rely on a unified digital multi services infrastructure that combines cable-based and wireless networks.

This digital multi services infrastructure is expected to be economic, safe, multi purposes and future proof to enable the sustainability of the city with regard to its digital services strategy and roadmap.

Until now silo and vertical ICT have been mainly taken into consideration to deploy services. For a few years now, various smart city efforts and initiatives suggest to strongly adopt a transversal approach in which services share a common Internet Protocol (IP) network, co-operate between each other and furthermore enable third parties to leverage the value offered by the power of data mining and big data processing.

A common and shared multi services architecture for the city's digital services is therefore needed to achieve the city's goals and ambitions at a reasonable cost of ownership and of operation, in shorter time, while strongly taking into consideration the eco efficiency of the different elements of the ICT deployments.

Introduction

Today digital life is leading major evolutions in the expectations that peoples and enterprises have towards the public administrations. As the local representative and interface, the municipality is in front line. The boom of the mobile Internet economy has created many new types of services which requires the city to evolve and adapt to such new behaviours from their target audiences.

City parking or tourism attractiveness are two simple examples of such digital revolution. In both cases, one expects to have access to digital services which respectively facilitate the discovery of an available parking place or to the accessibility of local public transportation facility such as bus, tram and even city bikes.

These digital services have increased the requirements of the ICT infrastructures of the city and amplified the need for a more sustainable Information Technology (IT) design. Smart digital city parking service requires sensors to be deployed within the field, that their real-time status (busy of available parking place) are transmitted through a data network and that a digital service leverage this information to be made available to the driver but also to the financial department in case of the parking usage has to be charged.

Today many city applications are to be seen as island or silo application and have their own network, own software platform and as a result different operations and maintenances. A common architecture will reduce this multiplication of networks and software solutions while improving the economical and energy efficiently costs.

The present document contains information which covers topics such as physical network installation, network transmission implementation, digital services deployments through efficient Next Generation Network (NGN).

The generic IP metropolitan network which is introduced suggests a multi layers design gathering the engineering best practices that telecom service providers regularly follow when deploying a tier 2 telecommunication infrastructure.

Furthermore, the present document presents how urban asset and related street furniture can play a role in the enhancement of the sustainability of the city. Through digital engineering, these urban assets can be promoted to a role which provides additional services beyond their native one.

1 Scope

The present document details measures which may be taken to ease the deployment of smart new services and their multiservice street furniture of digital multiservice city within the IP network of a single city or an association of cities administratively clustered. Furthermore, the suggested measures will enable to engineer a reliable common networking infrastructure which can improve the Total Cost of Ownership (TCO) for the public administration while improving the energy efficiency of the overall deployment.

The present document also lists the requirements which have led to this common architecture.

Clause 4 presents a suggestion of an engineered digital multiservice city.

Clause 5 introduces the active role categorized urban assets can play in the delivery of digital services across the territory of the city.

Clause 6 reviews the spread efforts within the standardization organizations for the digital multiservice city.

Clause 7 suggests both the common engineering required to transform an urban asset into an active network nodes of the digital multiservice city while presenting a concrete illustration of network design for one of the categories.

This will enable the proper introduction and implementation of a new service, application or content within the city digital portfolio on a unified energy efficient network, though it is not the goal of the present document to provide detailed standardized solutions for network architecture.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

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2.2 Informative references

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NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TS 110 174-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Sustainable Digital Multiservice Cities (SDMC); Broadband Deployment and Energy Management; Part 1: Overview, common and generic aspects of societal and technical pillars for sustainability".

[i.2] ETSI TS 105 174-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Energy Management; Part 1: Overview, common and generic aspects".

[i.3] ETSI TR 105 174-4: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment - Energy Efficiency and Key Performance Indicators; Part 4: Access networks".

[i.4] ETSI TS 105 174-4-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Energy Management; Part 4: Access Networks; Sub-part 1: Fixed access networks (excluding cable)".

[i.5] ETSI TS 102 973: "Access Terminals, Transmission and Multiplexing (ATTM); Network Termination (NT) in Next Generation Network architectures".

[i.6] ETSI TR 103 375: "SmartM2M IoT Standards landscape and future evolutions".

[i.7] AIOTI Recommendations for future collaborative work in the context of the Internet of Things Focus Area in Horizon 2020.

NOTE: Available at https://ec.europa.eu/digital-single-market/en/news/aioti-recommendations-future-collaborative-work-context-internet-things-focus-area-horizon-2020.

[i.8] Light Fidelity TED Talk: "Wireless data from every light bulb".

NOTE: Available at http://www.ted.com/talks/harald_haas_wireless_data_from_every_light_bulb.

[i.9] IEEE 802.11™: "IEEE Standard for Information technology -- Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[i.10] IEEE 802.11s™: "IEEE Standard for Information Technology -- Telecommunications and information exchange between systems--Local and metropolitan area networks--Specific requirements -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment 10: Mesh Networking".

[i.11] IEEE 802.15™: "Visible Light Communications (VLC)".

[i.12] IEEE 802.15.4™: "IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs)".

[i.13] IEEE 802.11ah™: "IEEE Draft Standard for Information Technology -- Telecommunications and Information Exchange Between Systems-Local and Metropolitan Area Networks-Specific Requirements -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Amendment 2: Sub 1 GHz License Exempt Operation".

[i.14] IETF RFC 3031: "Multiprotocol Label Switching Architecture".

[i.15] IETF RFC 4761: "Virtual Private LAN Service Using Label Distribution Protocol (LDP) Signaling".

[i.16] IETF RFC 4762: "Virtual Private LAN Service Using BGP for Auto-Discovery and Signaling".

[i.17] IEEE 802.3™: "Ethernet".

[i.18] IEEE 802.3az™: "IEEE Standard for Information technology -- Local and metropolitan area networks -- Specific requirements -- Part 3: CSMA/CD Access Method and Physical Layer Specifications -- Amendment 5: Media Access Control Parameters, Physical Layers, and Management Parameters for Energy-Efficient Ethernet".

[i.19] IEEE 802.3ab™: "IEEE Standard for Information Technology -- Telecommunications and information exchange between systems -- Local and Metropolitan Area Networks -- Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications -- Physical Layer Parameters and Specifications for 1000 Mb/s Operation over 4 pair of Category 5 Balanced Copper Cabling, Type 1000BASE-T".

[i.20] IEEE 802.3u™: "IEEE Standards for Local and Metropolitan Area Networks-Supplement -- Media Access Control (MAC) Parameters, Physical Layer, Medium Attachment Units and Repeater for 100Mb/s Operation, Type 100BASE-T (clauses 21-30)".

[i.21] IEEE 802.3z™: " Media Access Control Parameters, Physical Layers, Repeater and Management Parameters for 1,000 Mb/s Operation, Supplement to Information Technology -- Local and Metropolitan Area Networks -- Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications".

[i.22] IEEE 802.3af™: " IEEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems -- Local and Metropolitan Area Networks - Specific Requirements -- Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications -- Data Terminal Equipment (DTE) Power Via Media Dependent Interface (MDI)".

[i.23] IEEE 802.3at™: "IEEE Standard for Information technology -- Local and metropolitan area networks -- Specific requirements -- Part 3: CSMA/CD Access Method and Physical Layer Specifications -- Amendment 3: Data Terminal Equipment (DTE) Power via the Media Dependent Interface (MDI) Enhancements".

[i.24] IEEE 802.1q™: "EEE Standard for Local and metropolitan area networks--Bridges and Bridged Networks".

[i.25] Guide Pratique - Déploiement de la Boucle Locale Optique Mutualisée sur support aérien.

NOTE: Available at https://www.objectif-fibre.fr/wp-content/uploads/2015/12/121115-Guide-pratique-BLOM.pdf.

[i.26] IETF RFC 1034: "Domain Names - Concepts and Facilities".

[i.27] IETF RFC 1035: "Domain Names - Implementation and Specification".

[i.28] UEFI Forum: "ACPI specification".

NOTE: Available at http://www.uefi.org/specifications.

[i.29] IETF RFC 2474: "Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers".

[i.30] IETF RFC 2475: "An Architecture for Differentiated Services".

[i.31] Recommendation ITU-T G.9959: "Short range narrow-band digital radiocommunication transceivers - PHY, MAC, SAR and LLC layer specifications".

[i.32] IEEE 802.1D™-2004: "IEEE Standard for Local and metropolitan area networks: Media Access Control (MAC) Bridges".

[i.33] IEEE 802.11e™-2005: "IEEE Standard for Information technology -- Local and metropolitan area networks -- Specific requirements -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications -- Amendment 8: Medium Access Control (MAC) Quality of Service Enhancements".

[i.34] IEEE 802.11ad™-2012: "IEEE Standard for Information technology -- Telecommunications and information exchange between systems--Local and metropolitan area networks--Specific requirements -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications -- Amendment 3: Enhancements for Very High Throughput in the 60 GHz Band".

[i.35] IEEE 802.11ac™: "IEEE Standard for Information technology -- Telecommunications and information exchange between systems -- Local and metropolitan area networks -- Specific requirements -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications -- Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz".

[i.36] IEEE 802.3bv™: "IEEE Standard for Ethernet Amendment: Physical Layer Specifications and Management Parameters for 1000 Mb/s Operation Over Plastic Optical Fiber".

[i.37] 3GPP specifications.

NOTE: Available at http://www.3gpp.org/specifications/specifications.

3 Definition of terms and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

digital multiservice cities: cities using digital infrastructure which consists of a single unified high-speed networking infrastructure that allows the ICT systems of the complete city services departments to interconnect seamlessly and securely to each other

street furniture: collective term for objects and pieces of equipment (subcategory of the urban assets), installed on city streets, city roads, and public areas under responsibility of the city for various purposes

NOTE: These objects and equipment belong to the wider terminology of the urban assets as named by cities.

urban asset: collective term to qualify the physical assets which belong to a city and which are located across its territory, in streets, roads, public parks and associated urban constructions

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ACPI Advance Configuration and Power Interface
AIOTI Alliance for the Internet of Things Innovation

NOTE: In particular AIOTI WG3 on IoT Standardization.

AP Access Point
ATTM Access, Terminals, Transmission and Multiplexing
BTS Base Transceiver Station
CCTV Closed-Circuit TeleVision
DNS Domain Name Service
Gbit/s Giga bits per second
HMI Human Machine Interface
ICT Information and Communication Technology
IEC International Electrotechnical Commission
IEEE Institute for Electrical and Electronics Engineers
IETF Internet Engineering Task Force
IIC Industrial Internet Consortium
IMT International Mobile Telecommunications
IoT Internet of Things
IP Internet Protocol
ISM Industrial, Scientific, and Medical
ISO International Organization for Standardization
ISP Internet Service Provider
IT Information Technology
ITU International Telecommunication Union
JTC Joint Technical Committee
Kbit/s Kilo bits per second
LAN Local Area Network
LP-LAN Low-Power Local-Area Network
LP-WAN Low-Power Wide-Area Network
LR-WPAN Low-Rate Wireless Personal Area Networks
LSP Label Switch Path
M2M Machine to Machine

MAC	Media Access Control
MAN	Metropolitan Area Network
MPLS	Multiprotocol Label Switching
NFC	Near Field Communication
NGN	Next Generation Network
NT	Network Termination
OASIS	Organization for the Advancement of Structured Information Standards
OCF	Open Connectivity Foundation
oneM2M	Partnership Project oneM2M launched by a number of SSOs including ETSI
ONVIF	Open Network Video Interface Forum
OS	Operating System
PoE	Power over Ethernet
POF	Plastic Optical Fiber
PSIA	Physical Security Interoperability Alliance
QoS	Quality of Services
RF	Radio Frequency
RFC	Request For Comments
SLA	Service Level Agreement
SP	Service Provider
SSID	Service Set IDentifiers
STF	Special Task Force
TR	Technical Report
TxRx	Transceiver equipment
UEFI	Unified Extensible Firmware Interface
UHD	Ultra High Definition
UTP	Universal Twister Pair
VLAN	Virtual Local Area Network
VLC	Visible Light Communications
VPLS	Virtual Private LAN Service
W3C	World Wide Web Consortium
WAN	Wide Area Network
Wi-Fi	Wireless Fidelity
WiGig	Wireless Gigabit
WMM	Wi-Fi Multimedia
WSN	Wireless Sensor Network

4 Multiservice digital infrastructure

4.1 A shared digital infrastructure as core foundation

The core foundation for a digital multiservice city is strongly tightened to the ability that the components of its ICT systems have to interoperate. To achieve this goal, a city should install a shared communications infrastructure that will allow the ICT systems of the complete services departments to interconnect seamlessly and securely to each other.

4.2 Management of the various network cabling infrastructures of the city

Performant ICT requires the access to a high-speed network. To achieve the goal of an ubiquitous digital access the city network backbone should span across the entire territory. When seen through the silos approach, the deployment of such a broadband network architecture, mainly composed of optical fibre and most probably high-speed wireless point to point links, on a large geographical scale is a complex and expensive civil engineering challenge. However, when seen through the cross-domain approach, evidence demonstrates the benefit of sharing passive infrastructure amongst different city departments of city partners such as utilities.

Numerous city network infrastructures can be leveraged to achieve this strategy:

- Access to electrical power distribution infrastructure.

- Access to ducts, trenches.
- Access to lighting infrastructure.
- Access to water distribution infrastructure.
- Access to traffic control infrastructure (e.g. traffic lights, signs, pipes, etc.).
- Access to gas distribution infrastructure.
- Access to district heating infrastructure.
- Access to sewer collecting infrastructure.
- Access to city infrastructure of private users/operators (e.g. telecommunications and cable operators) through renting pipe spaces, access to poles/masts, etc.).

Furthermore, other passive city assets such as real estate properties (technical room facility), conduits, manholes, cabinets, lampposts, poles, masts, antennaes, towers and other supporting constructions could also play an important role in the design of the digital multiservice city infrastructure.

Best practices in network architectures organize the infrastructure topology into a multi layered structure which spans across the geographical area to deserve at city scale or urban metropolis scale:

- Layer 1: Digital multiservice city core network:
  - The core network provides high-speed and redundant forwarding services to move the data packet between the distribution nodes which span across the city area. The core nodes (usually routers) are commonly the most powerful, in terms of forwarding power; they define the Wide Area Network (WAN). When city communication networks interconnect to each other, some of these nodes also acts as Metropolitan Area Network (MAN) inter-exchanges nodes. Current appropriated bandwidth are high speed links such as Gigabit and 10 Gigabits or higher speeds.
- Layer 2: Digital multiservice city distribution Network:
  - The distribution network is often referred as the multiservice delivery level which offer several smart layers' functionalities for the various policies related to data packet routing, data packet filtering and Quality of Services (QoS). The distribution nodes (usually routers and switches) are mainly dedicated to connecting the network sites (LAN) to each other; their links to the network sites are often referred as last mile connections. Appropriate dispersal of these network nodes across the city geographical area makes them also an appropriate place to connect special delivery network elements, such as the municipality urban assets. Current appropriated bandwidth are high speed links such as Gigabit (and potentially 10 Gigabits).
- Layer 3: Digital multiservice city access Network:
  - The access network is often referred to the desktop layer. The access nodes (usually switches) have the main concern to connect the end hosts (workstation, server, enterprise devices: wireless access point (AP), printer, scanner, IP phone/camera, etc) to the city network infrastructure. The proximity of these nodes to the end devices makes them also an appropriate place to deliver secured electricity power (Power over Ethernet, PoE IEEE 802.3af [i.22] or IEEE 802.3at [i.23]) to low consumption devices (Wi-Fi AP, IP phone/camera, IoT gateway, etc). Current appropriated bandwidth are high speed Gigabit connections.

When reaching the network site layer, the hierarchy of the infrastructure topology can be further organized in stratums to fit the actual architectural structure of the local area (single or multi floors house/building, a multi constructions administrative district/campus) to be served. Typical network topology for LAN access includes star, mesh, tree, and clusters.

The digital multiservice delivery across the city-wide area implies to cope with multiple distances ranges. Core node links can deal with long distances which ranges from km to tens of km whereas distribution nodes links deal with distances from hundreds of metres to a km.

Off course, the transmission capability to achieve such distances depends on the physical communication medium: optical fibre is nowadays the preferred media to succeed in the delivery of multi (tens/hundreds) gigabits in long distances (core/distribution) links through optical transmissions. However, in various cases electrical transmissions over copper (twisted pair or coax) or wireless links can still be delivering acceptable high-speed data rate for distribution network links.

ETSI TR 105 174-4 [i.3] and ETSI TS 105 174-4-1 [i.4] detail measures which may be taken to improve the energy management of access networks for broadband deployment.

As far as possible, the city should do everything to have total control over its digital multiservice city infrastructure. In other words, it is valuable and advantageous for the city to deploy its own physical networking fibre connectivity links when technically feasible. When considered in a mid (3 years) to long term (10 years) strategic vision, having the ownership of the networking links is smarter than having contractual access to a service provider (SP) infrastructure.

Besides such economical considerations, there are various technical reasons which drive the city to deploy its own physical fibre network infrastructure or to contract, from a carrier, for dark (unlit) fibre links or to rent ducts from third parties to install its own cables:

- Freedom of the optical transmission standard: network bandwidth depends of the fibre transceivers which are bound at the extremities of the fibre link and the length of this one. According to the link needs, the municipality can lit the fibre with the most appropriate transceiver (from a single wavelength to wavelength-division multiplexing, from gigabit to multigigabits). Should a link speed need to increase, the municipality has the freedom to upgrade the transceivers.

- Freedom of the digital transmission standard: digital data transmissions can be operated by various technologies such as Ethernet, MPLS, etc. According to the engineering of the digital services and the requirement for network resilience one can be more suitable than the other. Network size, number of digital services, security concerns, multi-homing requirement, etc. are concerns which drives the choice of the optimal transmission standard.

- Ease of introduction of new digital services: to leverage a single physical network infrastructure sharing while delivering to each digital service within its own controlled environment, the municipality can either chose to introduce a new IP service by the means of a complementary VLAN in Ethernet, a complementary LSP in MPLS, or even by the assignment of a specific light wavelength which virtualizes the link at the optical level.

- Freedom of the choice of ISP: different Internet access might be required to be served by different service providers. While public administration agents require access to specific Internet service providers with specified technical SLA (redundancy, low latency, security, etc.), schools, libraries, police, citizen free public Internet, IoT sensors, etc. may use other service providers.

ETSI TS 105 174-1 [i.2] focuses on the best practices for cabling and installations and transmission implementation independently from the ownership of these infrastructures. ETSI TS 102 973 [i.5] describes a proposal of requirements for a Network Termination (NT) device in Next Generation Access Networks.

Deploying networking links includes planning and routing, obtaining permissions, creating ducts and channels for the cables, and finally installation and connection. When the situation permits, aerial links installation has to be preferred instead of digging the streets or sidewalks. In that concern, Objectif Fibre organization from the Federation des Industries Electriques, Electroniques et de Communication (FIEEC) has published a practical guide to deploy shared local optical infrastructure over aerial support [i.25].

However, there are various situations in which completely following such a strategy is simply unfeasible. In such cases, when contracting with an SP, passive network links (e.g. dark fibres) have to be preferred over active network links (e.g. leased line).

Digital service end points are usually distant from their access nodes in range from a few metres to a few hundred metres. As for the other communication layers, speed, achieved distance and access flexibility depend on the physical medium in use. Cable free connectivity offered by wireless technologies such as Wi-Fi (Electromagnetic Communication, EM) or Li-Fi [i.8] (an improvement of Visible Light Communication, IEEE VLC [i.11]) deliver suitable speeds, to the user desktop. From hundreds of gigabits over a few metres with LiFi (under certain conditions) up to multi-gigabits over hundreds of meters for existing contemporary IEEE Wi-Fi standards (e.g. IEEE 802.11ac [i.35]: 1 Gbit/s, IEEE 802.11ad [i.34]/WiGig [i.13]: 4 Gbit/s).

Current trends raised by the fields of IoT and M2M give to low speed (few kbit/s or hundred kbit/s) wireless communication technologies a significant role to play into the digital multiservice city infrastructure. Connectivity in this low speed and low power wireless network access can be categorized into two main viewpoints: short distance (LR-WPAN, LP-LAN) and long distance (LP-WAN).

In the former viewpoint, connected objects join the IoT wireless (mainly in unlicensed RF ISM band) gateway hooked to the city infrastructure at the Access Network layer whereas in the later viewpoint the connected objects join the IoT Base Transceiver Station (BTS) of a mobile operator network infrastructure (using its licenced RF band). ETSI TR 103 375 [i.6] provides a complete landscape view on these IoT technologies for Smart Cities.

Regarding the data transport technology, it is clear that IP (v4 and v6) and Ethernet [i.17] are the most suitable addressing and data transmission protocols to be deployed for the digital multiservice city infrastructure layers. Appropriate addressing plan, network hierarchy, security policies such as packet filtering and firewalling rules as well as and related QoS support have to be well engineered to achieve the design of a digital multiservice city delivery infrastructure.

Furthermore, although Ethernet has been proven to be a good transport technology for WAN, large city core network may need to consider other types of carrier class transport technologies such as Multiprotocol Label Switching (MPLS, IETF RFC 3031 [i.14]) or Virtual Private LAN Service (VPLS, IETF RFC 4761 [i.15] and IETF RFC 4762 [i.16]).

However, these considerations as well as engineering details on optical network architectures are outside the scope of the present document.

5 Digital services delivery through the urban assets

5.1 Leveraging street furniture with digital technologies

Street furniture is a collective term for objects and pieces of equipment installed on city streets and city roads for various purposes. These urban assets include the objects listed in the following clauses. Many of these city urban assets can be leveraged to either contribute as:

- network access nodes within the multilayer mesh which constitute the unified digital communication infrastructure;
- a service distribution and wireless AP node towards end users or connected objects (sensors, actuators) of the IoT world.

5.2 Usages of billboards, streetlamps, bollards and various poles, benches and picnic tables

Most of these urban assets can play a role in the enhancement of the sustainability of the city. These assets can be promoted to a role which provides additional services beyond the native one.

For instance, these urban assets can be the operation points for:

- Communications as transmitter/receiver points for data communications through Li-Fi.
- Provide public Wi-Fi services as a new city infrastructure.
- Public security, through use of CCTVs (IP video security) on posts.
- Control of light attenuation levels.
- Environmental sensing (air quality, noise pollution monitoring).
- Environmental management through CCTVs.
- Traffic control through through CCTVs or radar.
- Parking (monitoring) availability and access through sensors and actuators.

- Smart meters reading.
- Sound level monitoring through sensors.
- Movement activity monitoring through motion sensors of CCTVs.
- Image sensing (proximity, pedestrian counter).
- Digital signage (way finding, traffic direction, civic information).
- Water level/flood monitoring.
- Etc.

Through these various data sources, intelligent cross domain analysis and processing (most probably through Big Data platform) can be leveraged to offer useful services to the city and it is audiences. Typical example includes the adaptation of the streetlamp illumination level according to environmental parameters such as lighting condition, proximity of a user, detection of an abnormal incident. Offering to the citizen a better quality of life could be a simple as sharing the harvested information related to the quality of the air or the presence of high levels of flower pollens in resting areas, green parks and other child playgrounds.

Beside data harvesting functions, these urban assets can be considered as information delivery points, to the proximity users, either through local display mechanism (e.g. info kiosks, interactive or not) either through digital service delivery pushing the contextualized information directly into the user mobile terminal (e.g. smartphone, tablet) via locally generated wireless access point (e.g. Wi-Fi, Bluetooth, Near Field Communication (NFC)) or through voice and data communication over cellular networks (e.g. via small cells).

5.3 Usages of bus or tram stops, taxi stands and phone boxes

Most of these urban assets can play a role in the enhancement of the sustainability of the city and the operations of their partners. These assets can be promoted to a role which provides additional services beyond the native one.

These urban assets have in common the particularity of being in places which concentrate significate numbers of individuals who standing there for a while and often expect precise details related to the service delivery (e.g. real-time-schedule, availability, traffic conditions, etc.).

One-dimensional approach for connecting such urban assets to the digital multiservice city network can be to connect dynamic display boards, CCTV camera or Wi-Fi hotspot. By adopting a multi-dimensional approach, innovative and sustainable new type of operation can be offered. Local facts such as the number of persons, the presence of disabled persons can be valuable information that can be taken into account by the IT system to take decisions and improve the dynamic operation of the transportation system.

Furthermore, as a place which concentrates significant number of individuals in a defined area, these urban assets may be considered as an appropriate location to deliver cellular network communications (e.g. via small cells). This would represent on one side the opportunity to improve the overall performances of the mobile network while opening a complementary channel for (geo)localized digital service information delivery directly into the user mobile terminal.

5.4 Usages of post box and waste trash

Most of these urban assets can play a role in the enhancement of the sustainability of the city and the operations of their partners. These assets can be promoted to a role which provides additional services beyond the native one.

These urban assets have in common a physical characteristic associated to a "level of spatial volume used".

By associating appropriated sensors, the cross-domain pillar associated with the data culture and appropriated Big Data processing can add value to:

- The optimization of the paths executed by the waste collecting trucks.
- The conservation of the state of cleanness of the city by avoiding overfilled bin.
- The optimization of the paths executed for the sent mail collection.

- The opening of the post boxes to other type of content to be shipped (e.g. e-commerce good delivery/return).
- Etc.

Associating appropriated sensors to waste trashes can also monitor air quality and pollution/ unpleasantness caused by odours in order to keep a good the quality of life for the surrounding peoples.

The position of the waste trashes on the street level is a strategic advantage, particularly in dense skyscrapers cities, when considering delivering Wi-Fi hotspot to the pedestrian, the surrounding vehicle or other city urban assets. Since the bins are located on street level, service coverage and signal quality can be outstanding as they the wireless network is not perturbed from any interference from the buildings.

5.5 Usages of traffic signs and traffic lights

Most of these urban assets can play a role in the enhancement of the sustainability of the city. On one hand, these assets can have their operations improved and on the other promoted to a role which provides additional services beyond the native one.

These urban assets have in common the functions to signal and communicate to the proximity users (e.g. pedestrians, motorists, cyclists, drivers and workers) important information but also to secure and regulate the associated traffic (e.g. road, street, highway, rail road, tram line, crossroads, railroad crossing).

These urban assets are traditional places where sensors (e.g. motion sensors, radars, CCTVs) are located and information presented (e.g. traffic lights, info screens, sound alerts).

However, recent digital technologies can still increase the benefits of such urban assets. Furthermore, the connection to the digital multiservice city network of the city can empower the cross domain pillar by enabling new types of innovative services.

These urban assets are often in proximity of a substantial number of individuals. Hence, they may be considered as an appropriate location to deliver cellular network communication (e.g. via small cells). This would represent on one side the opportunity to improve the overall performances of the mobile network while opening a complementary channel for (geo)localized digital service information delivery directly into the user mobile terminal or onto next generation connected devices such as automotive which would embed a screen right into the windshield to support the driver by displaying for example a focus on the nearest traffic sign(s).

Electronic paper coupled with a dynamic access to the digital multiservice network of the city can transform any fixed infographic traffic sign into an adaptive infographic which communicates different contextualized information to the proximity users. Such dynamic road signalling can also be of a benefit in the regulation and optimization of the traffic within the city (e.g. guidance to the nearest available parking place, guidance to the least crowded street).

Enabling alternative sustainable transportation mechanisms is within the concern of many city councils. Today, cycling is considered a significant instrument that cities stimulate to answer their sustainability concerns. Prioritizing cyclists when it rains can be achieved by associating heavy rain sensors to the traffic lights operation. Nevertheless, such dynamicity of operations should be handled with care. Connectivity to the digital multiservice city network should be available to ensure that the monitoring and global operation of the cross-over is performing well.

5.6 Usages of fountains, public lavatories, watering troughs, street gutters, storm drains and fire hydrants

Most of these urban assets can play a role in the enhancement of the sustainability of the city. These assets can be promoted to a role which provides additional services beyond the native one.

All of these urban assets are related to water. The origin of the water supply can be:

- water from a cave source;
- water from the distribution network;
- water from the sewing collecting network;
- water from a river;

- water from a wastewater treatment plant;
- etc.

For instance, these urban assets can be the operation points for:

- water source pumping (production) monitoring and control;
- water recycling (production) monitoring;
- water volume consumption monitoring and control;
- water quality monitoring;
- operational (pressure, temperature, hydraulic, etc.) parameters monitoring and control;
- servicing control (tap/valve: open, close, flow regulation) management and control;
- securing critical services (fire hydrant operation, water tower operation);
- water pollution (e.g. pollutant, decease microbe) containment;
- water flows (clean and dirty) monitoring;
- water leakage monitoring and control;
- water flooding (e.g. river level, drain sewer, street gutter) prevention.

Production, distribution, consumption, collection and treatment of waste water represents the full cycle in the water department. Good operation of such city responsibility is a key element of an urban system. Although numerous water services management standards have been developed there is a need for defining, through use cases, what IoT can bring into the scene to address sustainable development goals.

5.7 Usages of memorials, statues, and public sculptures or art

Most of these urban assets can play a role in the enhancement of the sustainability of the city. These assets can be promoted to a role which provides additional services beyond the native one and in full accordance with preservation of cultural heritage.

All of these urban assets are related to city history, local art, tourist attraction, etc. These urban assets can be a collecting point for various environmental information:

- Air quality monitoring.
- Noise pollution monitoring.
- Sound level monitoring.
- Movement activity monitoring.
- Etc.

But they can also be delivery point for the information related to the urban asset itself (artist, history, art description, etc.) through:

- A mobile terminal of the proximity users with:
  - Near Field Communication.
  - Bluetooth.
  - Wi-Fi.
  - Li-Fi.

- An associated Digital Human Interface:
    - Interactive display through touch screen.
    - Interactive display through camera motion tracking interface.

Digital technologies can also be a way to increase the attractiveness of the sites: interactive experiences such as adaptive lightning, voice interactions, virtual complementary educational content projections, etc.

Beside data harvesting functions, these urban assets can be considered as information delivery points, to the proximity users, either through local display mechanisms (e.g. info kiosks, interactive or not) either through digital service delivery pushing the contextualized information directly into the user mobile terminal (e.g. smartphone, tablet) via locally generated wireless access point (e.g. Wi-Fi, Bluetooth, Near Field Communication (NFC)) or through voice and data communication over cellular networks (e.g. via small cells).

6 Technologies which leverage the digital sustainability of a city

6.1 Spread efforts for the digital multiservice city

Specialist Task Force 505 (STF 505) is a group of experts, funded by the European Commission and supported by ETSI, commissioned to provide on the one hand an in-depth analysis of the IoT Standardization landscape and on the other hand, an identification of the IoT standardization gaps.

STF 505 technical recommendation ETSI TR 103 375 [i.6] provides an overview of the IoT standards (requirements, architecture, protocols, tests and related open source projects) for the various landscape introduced by *"IoT LSP Standard Framework Concept"* [i.7] from the Alliance for the Internet of Things Innovation (AIOTI).

The Internet of Things requires and triggers the development of standards and protocols in order to allow heterogeneous devices to communicate and to leverage common software applications. Several standardization initiatives currently co-exist, in individual standardization organization or partnerships (e.g. ETSI SmartM2M, ETSI SmartBAN, ITU-T, ISO, IEC, ISO/IEC JTC 1, oneM2M, W3C, IEEE, OASIS, IETF, etc.) and also in conjunction with a number of industrial initiatives (e.g. All Seen Alliance, Industrial Internet Consortium (IIC), Open Connectivity Foundation (OCF), Thread protocol, Platform Industry 4.0, etc.).

It is therefore necessary to understand the global dynamics of IoT standardization in order to leverage on existing standardization activities, if relevant, vis-à-vis existing initiatives and to ensure a thorough understanding of market needs and requirements.

ITU-R is working on the future International Mobile Telecommunications (IMT) for 2020 and beyond, that covers all aspects for enhanced mobile broadband telecommunication including Internet of Things (IoT). Enhanced mobile broadband networks enable high-speed and ultra-reliable mobile (Internet) connectivity to applications such as video streaming/UHD screens, work and play in the cloud, voice, augmented/virtual reality, industrial automation (M2M), smart grids, self-driving cars, smart homes/buildings and smart cities.

Sustainable digital city content is made up of many services, e.g. smart transportation, smart home, smart waste management to mention just a few. Clause 6 of ETSI TR 103 375 [i.6] focuses on the standards that are available to enable the ICT systems of a city to function as a clever and performing single integrated system.

7 Engineering of the urban assets (street furniture)

7.1 Common engineering

Serious evolutions in the field of fixed and mobile connectivity and wireless contactless technologies are turning urban, passive physical assets into smart, connected street furniture which can interact in the city with the people offering contextualized contents. These interaction points should be able to communicate with inhabitants, visitors, travellers with the help of digital devices which could be mobile terminals in their hands (smartphone, tablet, etc.) or embedded in a vehicle (car, bike, bus, train, etc.) as well as Human Machine Interfaces (HMI) attached to the urban assets itself.

To provide services beyond the function for which they are engineered, street furniture and city urban assets in general should be connected to the digital multiservice city infrastructure. Interconnecting these elements should enable the municipality and related partners, to leverage the cross domain and data culture pillars.

To leverage network connectivity and digital service functions, the urban asset should be powered by electricity. The electrical power may be delivered by a permanent link to the electrical distribution network remotely fed or may be consumed from a local battery source feed by solar panel or alternative power generating devices.

Energy which is consumed by the urban asset in performing its digital services should be monitored and appropriate levels of energy saving should be applied when possible. The monitoring of the consumed energy should be performed in centralized operations. However, energy saving capabilities (e.g. standby mode, sleep mode) may operate in a decentralized manner which can be on the level of the urban asset itself.

Connected urban assets are part of the whole Internet of Things sphere. As such, smart urban assets contain hardware platforms with embedded computing platform running firmware and Operating System (OS). These hardware platforms can leverage UEFI Forum Advance Configuration and Power Interface (ACPI [i.28]) specifications for power management.

When the urban asset is not connected to a permanent source of electrical energy, appropriate engineering should be applied to the battery capacity to enable the digital services functions to operate without any interruptions also during the recharging cycles.

Urban assets should require regular voltage (220 Vac) or low power voltage (48 Vdc) to operate.

Urban assets should be considered as leaf node of a network for data collection and processing. When interconnecting with the digital multiservice city network, the urban asset should attach to the access network layer. However, in certain cases the urban asset may be attached to the distribution network layer. Such situations are, in a non-exhaustive way, when:

- the node is enabling other network nodes to attach to the network;
- the node is acting as part of a meshed network;
- the node is performing specific network services (e.g. data packet routing/filtering, QoS); etc.

When the digital features set includes such function the urban asset should be considered as a layer 3 access node.

Physical network connectivity of the urban asset to the digital multiservice city infrastructure should be correctly engineered according to network characteristics required for the provided digital features set:

- low latency services should be associated with fibre connectivity;
- bandwidth intensive services should be associated with fibre connectivity;
- high upstream data rate services should be associated with fibre connectivity;
- low data rate service should be associated with wireless connectivity.

When the digital features set includes mission critical functions, the urban asset should be connected to at least two network nodes of the access layer or the distribution layer.

Network addressing of the urban asset should use IP technology and should support IPv4 and IPv6. Technologies such as Network Address Translation should be banned.

When an urban asset is considered as an access layer node which aggregates several concurrent digital services, the urban asset should be capable to identify and provide services differentiation in order to ensure the delivery of the appropriate Quality of Service to each of the leaf nodes which require it. Networking technologies such as:

- IETF Type of Services Diffserv protocol (IETF RFC 2474 [i.29], IETF RFC 2475 [i.30]) to differentiate services on the IP network layer.
- IEEE Class of Services (IEEE 802.1p [i.32]) for Ethernet Virtual LAN (IEEE 802.1q [i.24]) to differentiate services on the Media Access Control (MAC) of the Ethernet network layer.
- Wi-Fi Multimedia (WMM IEEE 802.11e [i.33]) to differentiate services on the Media Access Control (MAC) of the Wi-Fi network layer.

When an urban asset is considered as an access layer node for non IP digital leaf nodes (e.g. sensor, actuator), the urban asset IP identity should be used on behalf of this network leaf node. Furthermore, if these complementary digital technologies offer any service quality feature, they should be used to deliver end to end QoS when necessary.

In order to facilitate the IP addressing of the urban asset, a dedicated network hostname associated with an appropriate network domain name should be defined in a Domain Name Service (DNS, IETF RFC 1034 [i.26], IETF RFC 1035 [i.27]) directory. Beside the digital addressing scheme, the digital asset should be associated with a geolocation parameter indicating the geographical position within the city area. For fixed urban assets, the position can be identified by an operator; however, for mobile urban assets the position should be defined by mechanisms such as GPS, radio triangulation, etc.

The above technical engineering should be taken into consideration for each street furniture (urban asset) on a per use case situation. As introduced in clause 4.2, urban assets can be categorized into digital contextual purposes:

- Engineering of billboard, streetlamp, bollard and various poles, bench and picnic table.
- Engineering of bus or tram stop, taxi stands and phone box.
- Engineering of post box and waste trash.
- Engineering of traffic sign and traffic light.
- Engineering of fountains, public lavatory, watering trough, gutter, storm drain and fire hydrant.
- Engineering of memorial, statue, and public sculpture or art.

The engineering of these digital contextual purposes will be described into separated technical specification. These documents will be complementary individual specifications for these network entity (leaf nodes) and network sub-systems (IoT nodes gateways/bridges) of the presently introduced digital multi service city Next Generation Network. Clause 7.2 introduces the suggested technical engineering architecture for the first urban asset category.

7.2 Engineering of billboard, streetlamp, bollard and various poles, bench and picnic table

The urban assets can play a role in the enhancement of the sustainability of the city by providing additional services beyond the native one.

This street furniture can, with appropriated structural layouts (build-in, adjusted or revised), be promoted to a network node for various communication technologies to either harvest data of or to provide communication facilities to other network nodes.

Figure 1 shows the content and external connectivity of a specific category of the city urban assets in a little more details though this diagram is intended to illustrate the types of equipment employed, not its internal connectivity. For the purposes of the present study, the boxes marked "TxRx" will be regarded as part of the access or distribution network, as appropriate and their power requirements included in the assessments for those networks.

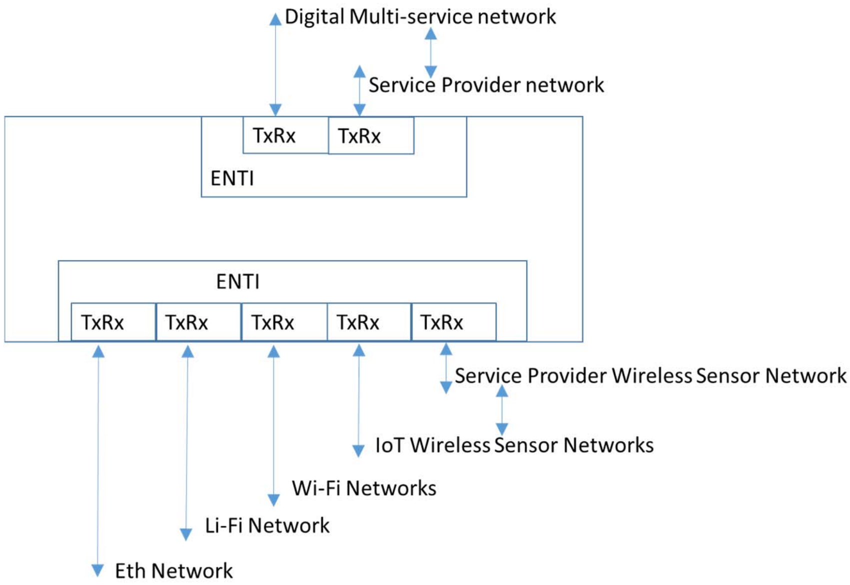

Figure 1: Engineering of urban asset

Connection link to the digital multiservice city network

Access to the digital multiservice city infrastructure from various parts within the city area implies to cope with multiple distances ranges. Urban assets node links can deal with distances which ranges from hundreds of metres to a few km.

The transmission capability to achieve such distances depends of the physical communication medium: optical fibre is nowadays the preferred media to succeed in the delivery of (multi) gigabits for such distances links through optical transmissions. Physical connectivity of the street furniture to the digital multiservice city network should be point-to-point fibre link to the nearest access or distribution node. However, in various cases electrical transmissions over copper (twisted pair or coax) can still be delivering acceptable high-speed data rate for the connection to the digital multiservice city infrastructure.

ETSI TR 105 174-4 [i.3] and ETSI TS 105 174-4-1 [i.4] detail measures which may be taken to improve the energy management of access networks for broadband deployment.

To the extent possible the city shall do everything to have total control over the urban asset link to the digital multiservice city infrastructure. In other words, it is valuable and advantageous for the city to deploy its own physical networking fibre connectivity links when technically feasible. When considered in a mid (3 years) to long term (10 years) strategic vision, having the ownership of the networking links is smarter than having contractual access to a service provider (SP) network infrastructure.

Beside such economical considerations, there are various technical reasons which drive the city to deploy its own physical fibre network infrastructure or to contract, from a carrier, for dark (unlit) fibre links:

- Freedom of the optical transmission standard: network bandwidth depends of the fibre transceivers which are bound at the extremities of the fibre link and the length of this one. According to the link needs, the municipality can light the fibre with the most appropriate transceiver (from a single wavelength to wavelength-division multiplexing, from gigabit to multigigabits). Should a link speed need to increase, the municipality has the freedom to upgrade the transceivers.

- Freedom of the digital transmission standard: digital data transmissions can be operated by various technologies such as Metro Ethernet, MPLS, etc. According to the engineering of the digital services and the requirement for network resilience one can be more suitable than the other. Network size, number of digital services, security concerns, multi-homing requirement, etc. are concerns which drives the choice of the optimal transmission standard.

- Ease of introduction of new digital services: to leverage a single physical network infrastructure sharing while delivering to each digital service within its own controlled environment, the municipality can either chose to introduce a new IP service by the mean of a complementary VLAN in Ethernet, a complementary LSP in MPLS, or even by the assignment of a specific light wavelength which virtualizes the link at the optical level.

- Freedom of the choice of ISP: different Internet access might be required to be served by different service providers. While public administration agents require access to specific Internet service provider with specified technical SLA (redundancy, low latency, security, etc.), schools, libraries, police, citizen free public Internet, IoT sensors, etc. may use other service providers.

ETSI TS 105 174-1 [i.2] focuses on the best practice for cabling and installations and transmission implementation independently from the ownership of these infrastructures. ETSI TS 102 973 [i.5] describes a proposal of requirements for a Network Termination (NT) device in Next Generation Access Networks.

Data communication service

To deliver data connectivity to neighbourhood network nodes towards the digital multiservice city network, the urban asset may support the following set (or subset) of standardized technologies:

- Wireless networking: IEEE 802.11 [i.9] Wi-Fi:
  - Hotspot should support speed requirements: IEEE 802.11ac [i.35] and IEEE 802.11ah [i.13] and may support IEEE 802.11ad [i.34].
  - Hotspot should support services differentiations: multiple Service Set Identifiers (SSID) for services separation and IEEE 802.11e [i.33] for QoS.
  - Hotspot may support wireless meshing IEEE 802.11s [i.10].
- Fixed networking IEEE 802.3 [i.17] Ethernet:
  - Ethernet access ports should support Fast Ethernet and Gigabit Ethernet standard:
    - IEEE 802.3u [i.20] (100BASE-TX/UTP; 100BASE-FX/Glass Optical Fibre (GOF), Plastic Optical Fibre (POF));
    - IEEE 802.3ab [i.19] (1000BASE-TX/UTP);
    - IEEE 802.3z [i.21] (1000BASE-X/Glass Optical Fibre (GOF)); and
    - future IEEE 802.3bv [i.36] (1000BASE-X/Plastic Optical Fibre (POF)).
  - Energy efficiency should be considered according to IEEE 802.3az [i.18].
  - Ethernet switching should support multiservice separation (VLAN IEEE 802.1q [i.24]) and traffic priority (VLAN IEEE 802.1p [i.32]).
  - Local power source should be available by IEEE 802.3af [i.22] "Power over Ethernet" or IEEE 802.3at [i.23] "Power over Ethernet plus".
- Wireless networking: Li-Fi [i.8].
- Wireless networking: cellular networking (2G/3G/4G, etc.) [i.37].
- IETF Type of Services Diffserv protocol (IETF RFC 2474 [i.29], IETF RFC 2475 [i.30]) to differentiate services on the IP network layer when routing IP.

Environment sensing and operation service

The distribution of such urban assets within the city area enables to establish a significate sensing network for various types of services such as environmental sensing (e.g. air quality, noise level) through either locally connected sensors or through the connection to Wireless Sensor Network (WSN). Furthermore, as the urban asset has an identity on the digital multiservice city network, individual control of the native service (e.g. lightning) can be operated remotely.

When the urban asset is considered as an access layer node for non IP digital leaf nodes (e.g. sensor, actuator), the urban asset IP identity should be used on behalf of this network leaf node. Furthermore, if these complementary digital technologies offer any service quality feature, they should be used to deliver end to end QoS when necessary.

The urban asset may support non IP based Wireless Sensor Network such as those based on IEEE 802.15.4 [i.12] (e.g. 6LoWPAN, Zigbee™, Bluetooth™ low energy) and Recommendation ITU-T G.9959 [i.31] Z-Wave.

IP video surveillance service

To deliver data connectivity to IP camera (e.g. CCTV service, motion capture service, depth vision measurement, etc.), the urban asset should support Fast Ethernet and Gigabit Ethernet standard to enable high quality video streaming. Furthermore, to deliver power to the IP camera, the urban asset should support IEEE 802.3af [i.22] "Power over Ethernet" and IEEE 802.3at [i.23] (for motorized camera).

Fixed Ethernet connectivity, IEEE 802.3u [i.20] (100BASE-TX/UTP; 100BASE-FX/Glass Optical Fibre (GOF), Plastic Optical Fibre (POF)), IEEE 802.3ab [i.19] (1000BASE-TX/UTP), IEEE 802.3z [i.21] (1000BASE-X/Glass Optical Fibre (GOF)) and future IEEE 802.3bv [i.36] (1000BASE-X/Plastic Optical Fibre (POF)) should be preferred over wireless Wi-Fi connectivity to ensure service availability.

Standardization of IP video surveillance (IP CCTV) is driven by industry groups Open Network Video Interface Forum (ONVIF) and Physical Security Interoperability Alliance (PSIA).

History

Document history		
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