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TECHNICAL SPECIFICATION

Access, Terminals, Transmission and Multiplexing (ATTM);
Sustainable Digital Multiservice Communities;
Broadband Deployment and Energy Management;
Part 2: Multiservice Networking Infrastructure and Associated Street Furniture;
Sub-part 2: The use of lamp-posts for hosting sensing devices and 5G networking

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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 2 of a multi-part deliverable. Full details of the entire series can be found in part 1 [i.13].

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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Introduction

The "smart city" concept radically changes the management of the community it services.

The present document discusses the use of lamp-posts, pervasive in urban areas, as a physical infrastructure to host devices to provide data to support that evolving management model.

This re-purposing of the existing infrastructure can take advantage of the general replacement of existing light sources with high efficiency Light Emitting Diode (LED) lighting systems together with management technologies to control their operation.

A basic approach is to install circuitry to allow the subsequent installation of sensing devices which provide data directly to the community addressing parameters such as air and noise pollution. These devices do not demand substantial bandwidth within an access network and do not major demands on availability of connectivity (including power supplies).

In comparison, many of the services delivered to and for the community, will be founded on data analysis (Big or Fast Data) coming from a large number of connected devices.

The major challenges will not be the data itself, but how collect, distribute and transport it and the provision of the appropriate access networks in order to manage the connected devices, requiring connectivity with a high level of availability, in the most energy and cost-efficient manner.

The next generation of wireless networks designed as "5G" will radically change the services offered by mobile networks - not least recognizing the arrival of billions of connected devices constituting the Internet of Things (IoT), autonomous cars and drones (see Figure 1).

The 5G networks will need improved geographic coverage and enhanced bandwidth to carry higher volumes of data, with some services requiring very low latency (< 1 ms) and the need to guarantee a much higher degree of service continuity (availability) than current networks.

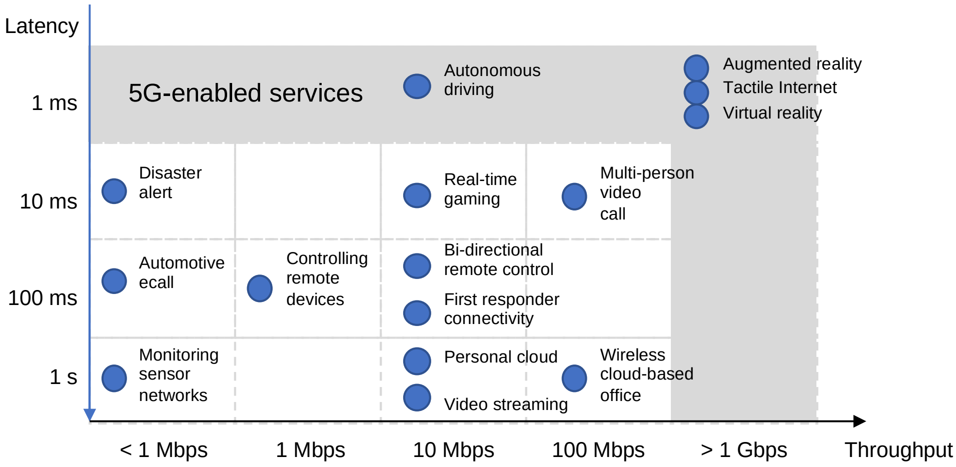


Figure 1: Examples of 5G service demands

The deployment of a 5G compliant infrastructure will have huge consequences in terms of number and variety of access points and will require substantial number of radio units to be installed at street level so to support new services such as autonomous driving. The existing lamp-post infrastructure presents an opportunity to host 5G Remote Radio Units (RRUs) which can avoid deploying a specific and costly infrastructure.

NOTE: 5G, together the need to deploy other connectivity technologies (LiFi, LoRa™, WiFi™, 4G, etc.), will increase the number of access points.

The 5G radio unit encompasses a series of equipment flavors which are identified as Macro base station, Mini-Macro cells, Microcells, Picocells, and Femtocells for whose characteristics are listed in Table 1:

- Macro equipment Base Station (BS) - for wide coverage - installed outdoors at higher heights (normally more than 20 m): In most cases, they will be located in the same sites as the macro-BS of the previous mobile generations but, to cover special traffic needs, it may occur they are installed at reduced height. The increased energy demand and the much higher availability need of the 5G equipment will pose tough challenges to the powering infrastructure and will likely require major upgrades, both in the power capabilities and the backup duration.

- Mini-Macro cells installed outdoors at low height (normally less than 12 m). These are designed to be quickly deployed when adding new sites, when there are increasingly requirements for capacity expansion and coverage issues in densely populated urban areas. Compared with traditional macro base stations, Mini-Macro cells feature smaller size, light weight, and environment integration that enables a time- and cost-effective network deployment.

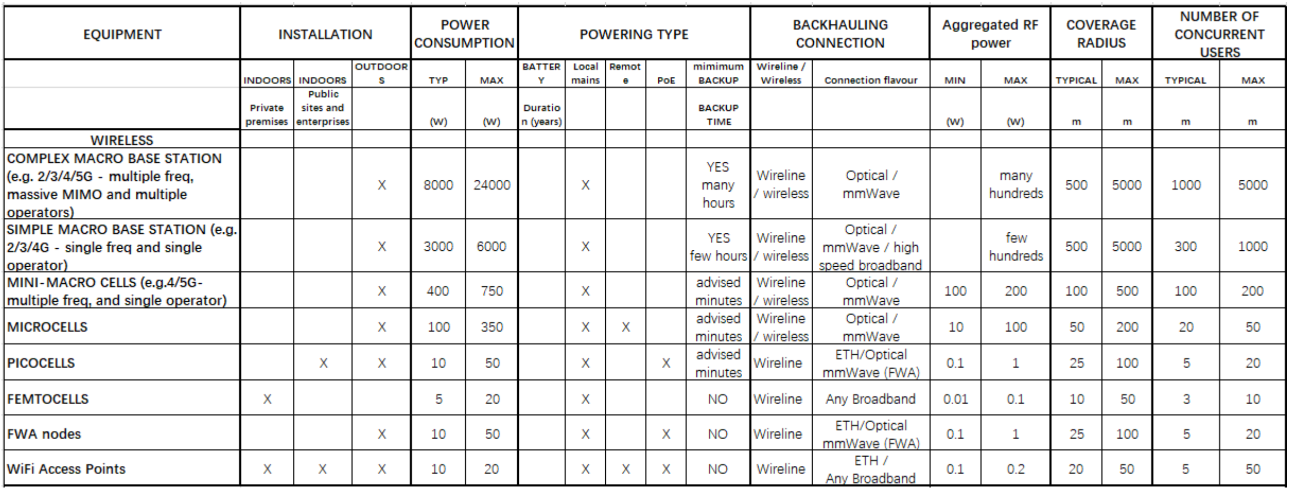
- Microcells installed outdoors at low height (normally less than 12 m. These are designed to support a large number of users in high data traffic areas, to solve coverage issues and to support very high frequency deployment capable of covering medium/large cells and suitable for application such as for smart cities, smart metro, etc.

- Picocells normally installed indoors, at ceilings. These are suitable for enterprises, shopping centres, stadium applications, etc., for extended network coverage and data throughput.

- Femtocells - normally installed indoors, at ceilings or table-top. these are small mobile base stations designed to provide extended coverage for residential and Small Offices Home Offices (SOHO) applications. Poor signal strength from a mobile operator's macro base stations is tackled using femtocell implementation. Femtocells are primarily introduced to offload network congestion, extend coverage and increase data capacity to indoor users.

The typical characteristics of radio cells are listed in Table 1 such as power consumption, coverage radius, number of users, indoor/outdoor installation, etc. It can be noted that the Mini-Macro cells, Microcells and FWA nodes are normally installed outdoors and appropriate to be mounted on the lamp-posts.

Table 1: Radio Units Characteristics



EQUIPMENT	INSTALLATION			POWER CONSUMPTION		POWERING TYPE					BACKHAULING CONNECTION		Aggregated RF power		COVERAGE RADIUS		NUMBER OF CONCURRENT USERS	
	INDOORS	INDOORS	OUTDOORS	TYP	MAX	BATTERY	Local mains	Remote	PoE	mimimum BACKUP	Wireline / Wireless	Connection flavour	MIN	MAX	TYPICAL	MAX	TYPICAL	MAX
	Private premises	Public sites and enterprises		(W)	(W)	Duration (years)				BACKUP TIME			(W)	(W)	m	m	m	m
WIRELESS																		
COMPLEX MACRO BASE STATION (e.g. 2/3/4/5G - multiple freq, massive MIMO and multiple operators)			X	8000	24000		X			YES many hours	Wireline / wireless	Optical / mmWave		many hundreds	500	5000	1000	5000
SIMPLE MACRO BASE STATION (e.g. 2/3/4G - single freq and single operator)			X	3000	6000		X			YES few hours	Wireline / wireless	Optical / mmWave / high speed broadband		few hundreds	500	5000	300	1000
MINI-MACRO CELLS (e.g.4/5G-multiple freq, and single operator)			X	400	750		X			advised minutes	Wireline / wireless	Optical / mmWave	100	200	100	500	100	200
MICROCELLS			X	100	350		X	X		advised minutes	Wireline / wireless	Optical / mmWave	10	100	50	200	20	50
PICOCELLS		X	X	10	50		X		X	advised minutes	Wireline	ETH/Optical mmWave (FWA)	0.1	1	25	100	5	20
FEMTOCELLS	X			5	20		X			NO	Wireline	Any Broadband	0.01	0.1	10	50	3	10
FWA nodes			X	10	50		X		X	NO	Wireline	ETH/Optical mmWave (FWA)	0.1	1	25	100	5	20
WiFi Access Points	X	X	X	10	20		X	X	X	NO	Wireline	ETH / Any Broadband	0.1	0.2	20	50	5	50

There are major concerns regarding the capital expenditure required to build and deploy an infrastructure with optimal coverage, reliability and quality of service and about the complexity of managing a huge number of contracts and permission with building owners for each equipment they intend to install. As a result, the use of lamp-posts as an existing physical infrastructure to host the RRUs of 5G networks represents an opportunity for the community to obtain revenue from third-party operators of the networks and also to obtain additional data to manage the increasingly "smart city". The opportunity for 5G network operators to manage a contract and permission with a single entity (the city or the public lighting operator) will drastically reduce the complexity and the bureaucracy of a city-wide deployment.

1 Scope

The present document addresses the opportunities and challenges offered by the use of lamp-posts to provide facilities supporting services required by sustainable digital multiservice cities and communities.

The replacement of existing luminaires by LED light sources offers an opportunity to increase the functionality provided by the lamp-posts - beginning with improved operational control of the lighting provided.

However, additional functionality can be supported by simultaneous installation of an electronics package to enable the lamp-post to host sensing devices. The present document describes the functions to be supported by this package together with consideration of power supply to any hosted sensing devices.

A more comprehensive replacement approach includes the incorporation of 5G services by the separate installation of wireless network components acting as a Remote Radio Unit (RRU). The present document describes the technical challenges associated with the physical installation, provision of power, cabling and other infrastructures necessary to meet the required level of availability for these services.

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/.

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 necessary for the application of the present document.

[1] EN 40-1:1991: "Lighting columns; Part 1: Defintions and Terms" (produced by CEN).

[2] ETSI EN 303 472 (V1.1.1): "Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for RAN equipment".

[3] IEC 60050-601: "International Electrotechnical Vocabulary (IEV) - Part 601: Generation, transmission and distribution of electricity - General".

2.2 Informative 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.

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] EN 50173-1: "Information technology - Generic cabling systems - General requirements" (produced by CENELEC).

[i.2] EN 50174-3: "Information technology - Cabling installation - Installation planning and practices outside buildings - General requirements" (produced by CENELEC).

[i.3] HD 60364 series: "Electrical Installations for Buildings" (produced by CENELEC).

[i.4] IEC 62368-3: "Audio/video, information and communication technology equipment - Safety - Part 3: DC power transfer through information technology communication cabling".

[i.5] IEEE 802.3bt™: "IEEE Standard for Ethernet Amendment 2: Physical Layer and Management Parameters for Power over Ethernet over 4 pairs".

[i.6] IEEE 802.3cg™: "10Mb/s Single Pair Ethernet".

[i.7] Recommendation ITU-T G.652: "Characteristics of a single-mode optical fibre and cable".

[i.8] Recommendation ITU-T G.657: "Characteristics of a bending-loss insensitive single-mode optical fibre and cable".

[i.9] Recommendation ITU-T K.50: "Safe limits for operating voltages and currents in telecommunication systems powered over the network".

[i.10] IEC 61140: "Protection Against Electric Shock Common Aspects for Installation and Equipment".

[i.11] IoTUK group: "The Future of Street Lighting".

NOTE: Available at https://iotuk.org.uk/wp-content/uploads/2017/04/The-Future-of-Street-Lighting.pdf.

[i.12] IEC 60479-2: "Effects of current on human beings and livestock - Part 2: Special aspects".

[i.13] 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".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

backhaul (network): fixed network interconnecting the BaseBand Units (BBUs), collecting/distributing data traffic from/to those BBUs, to/from core network access points

Base Station (BS): Network Telecommunications Equipment (NTE) which serves one or more cells within a coverage area of a mobile access network

big data: structured, semi-structured and unstructured data that has the potential to be mined for information and used in machine learning projects and other advanced analytics applications

core network: functional elements (that is equipment and infrastructure) that enable communication between operator sites (OSs) or equivalent ICT sites

Enhanced Mobile Broadband: one of three primary 5G New Radio (NR) use cases defined by the 3GPP as part of its SMARTER (Study on New Services and Markets Technology Enablers) project

fast data: application of big data analytics to smaller data sets in near-real or real-time in order to solve a problem or create business value

NOTE: The goal of fast data is to quickly gather and mine structured and unstructured data so that action can be taken. As the flood of data from sensors, actuators and Machine-to-Machine (M2M) communication in the IoT continues to grow, it has become more important than ever for organizations to identify what data is time-sensitive and should be acted upon right away and what data can sit in a database or data lake until there is a reason to mine it.

front-haul (network): network interconnecting the BaseBand Units (BBUs) or antennas connected to them, collecting/distributing data traffic from/to those BBUs, to/from Remote Radio Units (RRUs)

lamp-post: lighting column and lantern(s) it supports

lantern: protective case for a light fitting

lighting column: support intended to hold one or more lanterns, consisting of one or more parts: a post, possibly and extension piece and, if necessary, a bracket

NOTE 1: It does not include columns for catenary lighting.

NOTE 2: SOURCE: EN 40-1:1991 [1], clause 2.1.

low voltage: set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V for alternating current

NOTE 1: 1 500 V for direct current.

NOTE 2: SOURCE: IEC 60050-601 [3].

Massive IoT: applications that are less latency sensitive and have relatively low throughput requirements, but require a huge volume of low-cost, low-energy consumption devices on a network with excellent coverage

mid-haul (network): network interconnecting the BaseBand Units (BBUs) to/from antennas which provide wireless connections to Remote Radio Units (RRUs)

Network Telecommunications Equipment (NTE): equipment between the boundaries of, and dedicated to providing direct connection to, core and/or access networks

Radio Access Network (RAN): telecommunications network in which the access to the network (connection between user equipment and network) is implemented over the air interface

NOTE: SOURCE: ETSI EN 303 472 [2].

safety class: class rating in electrical appliances

NOTE 1: See IEC 61140 [i.10].

NOTE 2: Class I is based on the presence of an earthing terminal while Class II, also known as double insulated, does not need earthing terminal.

urban data platform: facility to integrate the large amount of data in cities, including energy, transport, crowdsourced data, etc. and provide holistic view of the information with the aim of improvement and development of innovative smart city services

3.2 Symbols

Void.

3.3 Abbreviations

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

3GPP	3rd Generation Partnership Project
5G	Fifth Generation
AC	Alternating Current
AWG	American Wire Gauge
BBU	BaseBand Unit
BS	Base Station
CPRI	Common Public Radio Interface
C-RAN	Centralized Radio Access Network
DC	Direct Current
eCPRI	evolved Common Public Radio Interface
eMBB	enhanced Mobile BroadBand
EU	End Users
FWA	Fixed Wireless Access
IEEE	Institute of Electrical and Electronics Engineers

IoT	Internet of Things
IT	Information Technology
LED	Light Emitting Diode
LiFi	Light Fidelity (wireless technology)
LoRa™	Long Range (wireless technology)
LTE-M	Long Term Evolution for Machines
LV	Low Voltage
LVDC	Low Voltage Direct Current
M2M	Machine-to-Machine
MIMO	Multiple Input-Multiple Output
mmWave	millimetre Wave
MNO	Mobile Network Operator
NB-IoT	Narrow Band Internet of Things
NFV	Network Functions Virtualisation
NR	New Radio
NSP	Network Service Platform
PA	Power Amplifier
PoE	Power over Ethernet
PtMP	Point to MultiPoint
PtP	Point to Point
QoS	Quality of Service
RAN	Radio Access Network
RF	radio frequency
RFT-C	Remote Feeding Telecommunication - Current limited
RFT-V	Remote Feeding Telecommunication - Voltage limited
RRU	Remote Radio Unit
URLLC	Ultra-Reliable and Low Latency Communications
UPS	Uninterruptable Power System
USB	Universal Serial Bus
V-RAN	Virtual Radio Access Network
VAC	Voltage Alternating Current
VCO	Voltage-Controlled Oscillator
VDC	Voltage Direct Current
WiFi®	Wireless Fidelity (wireless technology)

4 The path towards Smart street lighting

4.1 General

It is estimated that there are more than 60 million lamp-posts, or equivalent structures, supporting lanterns providing lighting for roads and other spaces across Europe.

NOTE: The figures in the present document show conventional lamp-posts but should be considered to represent any form of supporting structures for lanterns.

The current trend to replace the lights within the lanterns with LED technology offers considerable benefits to the community which are outside the scope of the present document. However, the replacement process offers the opportunity to make other changes to the components within the lamp-post to enable the provision of additional services of both direct and indirect benefit to the community.

Typical examples of such services are shown in Figure 2.

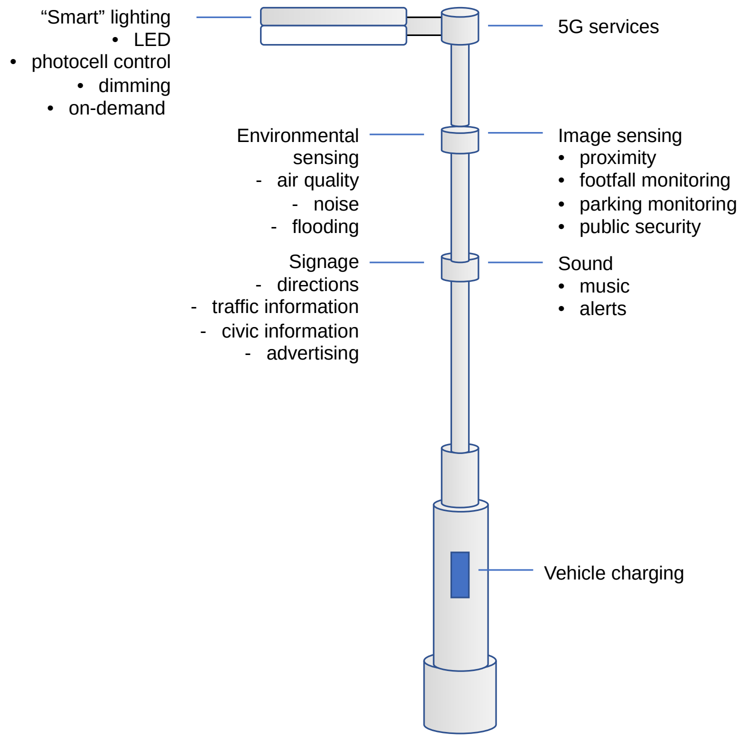


Figure 2: Examples of lamp-post service provisioning

Services of direct benefit to the community would be "smart" lighting, environmental sensing, image sensing, signage and sound. The power and data enabling these services to operated could be provided over the infrastructure already used to deliver power to the lamp-posts. Alternatively, the data could be provided over connections to existing wireless networks of third-party operators. Independent of its delivery mechanism, the data provided to and from the lamp-post is used directly by the community and the cost of producing, transporting and interpreting that data is borne by the community.

Indirect benefit to the community results from the revenue-earning opportunity of sharing of the lamp-post, as a part of a widely distributed infrastructure, with third-party providers such as those offering wireless telecommunications and vehicle charging. The demands for availability of data and power differs between such third-party services and also differs from those of the primary function of the lamp-post and the other services described above.

The present document specifically addresses the use of lamp-posts to host "direct benefit" services relating to sensing devices and "indirect benefit" services relating to the provision of 5G connectivity between End Users (EUs) and the Radio Access Network (RAN) via the RRU mounted on the poles and the onward connectivity BaseBand Unit (BBU).

The main advantages offered by lamp-posts for 5G connectivity are:

- a well-defined and ubiquitous distribution within urban environments which matches the demands for radio coverage from the RRU - providing reduced deployment costs and timescales;
- a height which facilitates propagation of the radio signal - both extending the coverage radius of each cell and minimizing the impairment produced by large vehicles such as public transport and goods vehicles.

However, the dramatic differences in the requirements for the supply of data and power to the lamp-posts for sensing devices as compared to 5G connectivity cannot be underestimated.

Table 2 provides a non-exhaustive list of the service groups and the detailed applications that could be supported by the 5G RRUs hosted by the lamp-posts and those applications are differentiated as "Massive IoT". "enhanced Mobile BroadBand (eMBB)" and "Ultra-Reliable and Low Latency Communications (URLLC)".

Table 2: Service areas and applications

Service group	Application	Massive IOT	eMBB	URLLC
Infotainment	Gaming (Ultra High Definition)		✓	
	Video (Ultra High Definition)		✓	
	Virtual reality		✓	
	Augmented reality		✓	
	Smart gadgets (toys, smartwatches, etc.)	✓		
	Robotics (home)		✓	
Home	Energy management	✓		
	Smart sensors (gas, electricity, water, etc.)	✓		
	Appliance control	✓		
	Intrusion detection	✓		
	Remote video watching		✓	
	Security issues; detection (leaks, fire, etc.)	✓		
Smart city	Utility monitoring (gas, electricity, water, etc.)	✓		
	Street smart light poles	✓		
	Public safety watching		✓	
	Traffic control			✓
	Parking management	✓		
	Waste management	✓		
Health	Road and buildings status	✓		
	Fall detection	✓		
	Remote diagnostic	✓		
	Health monitoring	✓		
	Robotic surgery			✓
Environment	Medication (management)	✓		
	Air quality	✓		
	Water quality	✓		
	Noise measurement	✓		
	Radiations	✓		
	Energy use	✓		
	Leakages (floods, chemical, etc.)	✓		
Industry	Drone watching		✓	
	Asset and stock management	✓		
	Robotic control - production automation			✓
	Production control and safety	✓		
Agriculture	Machine monitoring	✓		
	Soil monitoring (water, nutriments, etc.)	✓		
	Crop yield	✓		
	Storage yield management	✓		
Transports	Green house monitoring	✓		
	Traffic regulation	✓		
	Remote diagnosis	✓		
	Autonomous vehicles management			✓
	Watching drone management	✓		

A document entitled "The Future of Street Lighting" [i.11] published by the IoTUK group refers to the evolution of the functions of lamp-posts as follows:

- Stage 1: Switching to LED bulbs;
- Stage 2: Connected street lighting;
- Stage 3: New service development.

The present document adopts these terms.

The clauses 4.2, 4.3 and 4.4 explain the meaning and boundaries for each stage of evolution.

4.2 Stage 1: Switching to LED bulbs

Stage 1 is simply the replacement of the existing technology lighting fixture with those using LED technologies. LEDs offer longer lifetimes, lower energy consumption and reduced maintenance costs. Savings on energy consumption are estimated to be 50.

This is not of direct interest in the present document except that it defines an opportunity to initiate the other changes to the lamp-post functionality offered in Stage 2 (clause 4.3) and Stage 3 (clause 4.4).

4.3 Stage 2: Connected street lighting

Stage 2 overlays Stage 1 with a limited bandwidth network connectivity and control systems to:

- remotely monitor lighting performance: maintenance costs are reduced by detecting and raising a service alert when there is a problem with an LED;
- change light levels to match ambient light levels: street lights are switched on when fog or rain creates low daylight levels or dimmed when there is too much reflected glare (e.g. from snow cover);
- change light levels to match local activity: street lights integrated with motion sensors are switched on when pedestrians or cars pass;
- change light levels to alert the public: public safety personnel can increase lighting levels, or have lights flash, at locations where accidents or emergencies have occurred;
- measure energy consumption: measuring the consumption of each lamp-post.

This level of control uses an "urban data platform" to monitor and manage the performance of the lighting provided on the lamp-post.

The network connectivity varies and includes both wired solutions and wireless connections and the data represents a form of Massive IoT mentioned in Table 2.

The present document adds to this concept by specifying in clause 5.1 the functionality of electronic circuitry necessary to provide a connection to this urban data platform from sensors attached to lamp-posts to provide data relating to:

- intermittent polling of climatic conditions:
  - temperature;
  - pressure;
  - humidity;
  - precipitation;
  - wind;
  - ultraviolet UVA/UVB radiation;
- intermittent polling of environmental Key Performance Indicators:
  - noise;
  - air quality:
    - carbon dioxide;
    - nitrogen dioxide;
    - fine particulate matter;
- continuous monitoring:
  - instances of peak noise (e.g. gun-shot);

- video surveillance (e.g. traffic control).

It is recognized that not all lamp-posts will host the same (or any) sensors but the majority of the above sensors are subject to strict requirements for their location.

The electronic circuitry above is required to be able to communicate directly with the urban data platform using either the network solutions employed to manage the lighting, the 5G network described in clause 4.4 or other networks (e.g. 2G, 3G, 4G, LoRA™ and SIGFOX™).

4.4 Stage 3: New service development

Stage 3 represents the full migration of the lamp-post infrastructure to support 5G connectivity to EUs supporting as required the Massive IoT, eMBB and URLLC applications listed in Table 2.

While existing lamp-posts may be served by a power supply suitable to support Massive IoT applications, the existing power supplies may not be continuously available. This may be adequate for the electronic circuitry for the package of electronics meeting the objectives of Stage 2 evolution but is not adequate for those of Stage 3.

It is a real challenge to provide the number of infrastructural components needed to distribute 5G connectivity (and the widespread installation of sensors) with the associated demands for reliability, security, ubiquity and Quality of Service (QoS).

The costs and complexity of such deployments, involving many different stakeholders can slow the 5G network implementation because:

- many more RRUs are required due to the short wavelengths used to enable the service demands and RRUs need to be installed closer to each other and to the EUs compared to 3G and 4G solutions;
- however, very few (if any) lamp-posts will be served with a power supply with an appropriate quality and/or availability necessary to meet the demands of 5G RRUs;
- the maintenance of service requires not only provision of power and data to each lamp-post which is separate from the existing provision but may also require a network design that maintains the required services even if that provision of power and data fails at a given lamp-post.

The presence of multiple access networks and power supplies clearly represents a challenge for demarcation during installation and maintenance. The present document does not address vehicle charging but the risk to service provision can be considered to be exacerbated if other parties are involved in providing other power supplies to and in the lamp-posts.

5 Functionality and availability

5.1 Stage 2

5.1.1 Functionality

5.1.1.1 Data connection

Figure 3 shows the complete functional set for the sensor circuitry. It is recognized that not all lamp-posts will host the same (or any) sensors but the installation of a common circuit board capable of hosting all sensors offers advantages in terms of both cost and operational flexibility.

The present document does not specify the type of sensor devices or the interfaces between them and the data amalgamation circuitry.

A common set of sensors have to be selected for all lamp-posts in order to define the data amalgamation circuitry shown schematically in Figure 3.

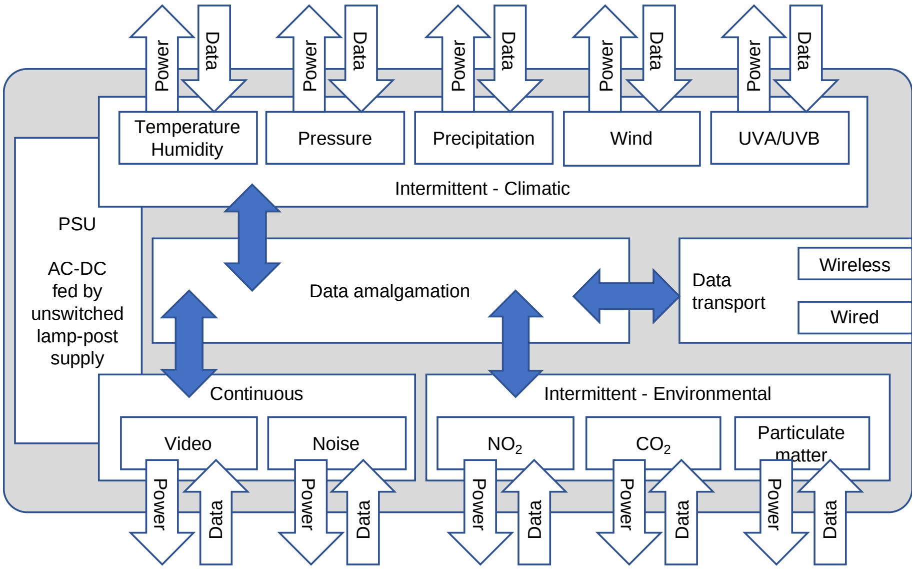


Figure 3: Examples of lamp-post service provisioning

The data transport technology has to be able to support either a wired or wireless connection to the urban data platform using either the network controlling the lamp-post itself or via a third-party operator's network (including the 5G connectivity) implemented under Stage 3.

Where battery-powered sensors are used, it is common to employ wide area, low power communications systems (e.g. NB-IoT, LTE-M, SIGFOX™, LoRa™) in order to maximize battery life and minimize the disruption and cost of battery replacement.

5.1.1.2 Power supply

There are number options, depending on the energy consumption of the sensors and by the communication system, including:

- an integrated battery - where sensors have particularly low energy consumption and communicate very limited amounts of data to the urban data platform;
- a local energy harvesting solution (e.g. solar panel) - the presence of a battery-backup is typically required as the energy to be harvested can be erratic;
- the power supply to the lamp-post - a battery providing back-up power is typically required as the supply may often be absent (e.g. during the day, during maintenance) and in any case such a solution is only practical for powering equipment that have low energy consumption (e.g. < 1 W);
- ad-hoc power supply remotely fed so to provide both the amount of energy needed (even tens of watts) and guarantee the needed service continuity - such systems can be those used for Stage 3.

It is considered that all the sensors on a given lamp-post would not require a power supply of more than 20 W unless specific requirements exist for video camera functionality (e.g. heating of camera enclosures, etc.).

The power provided to the sensors and protocol used to poll data from the sensors can either be:

- proprietary with each sensor potentially using a different supply voltage and interface protocol - this requires each sensor to be specified before the electronics package can be defined and designed; or
- implemented via existing standards such as Universal Serial Bus (USB), IEEE 802.3bt [i.5] or IEEE 802.3cg [i.6], this provides much greater flexibility in terms of changing the type of sensors installed - however this may result in increased power consumption, and physical dimensions, of the electronics package.

NOTE 1: Certain sensors may operate using power supplied from a local battery.

NOTE 2: Sensors may operate using power supplied from a local energy harvesting solution such as solar cell technology. In such cases, mechanical constraints should be taken into account, in particular the stresses the structure supporting the solar cell places on the lamp-post (see clause 5.1.2).

5.1.2 Availability

The first element of availability to be addressed is the physical capability of the population of lamp-posts in a given city to support the mass of the sensors and any local power supply solutions. It should be noted that additional mass can change the behaviour of the lamp-post, cause collapse and represent a safety risk when a transverse load is applied (e.g. resulting from wind or traffic accidents).

Typical lamp-posts are fed from 230VAC. There is no obvious problem with obtaining a power supply adequate to serve the sensor package via an AC-DC convertor connected to an unswitched input to the lamp-post (not the output of the on/off switch for the light).

The availability of the existing power supplies to the lamp-post should be assessed to determine its impact on the functionality of the sensor package taking the following into consideration:

- the majority of the data obtained via the sensors is not required on a continuous basis and, where necessary, a local battery may be applicable to maintain service following of power supply failure;
- if video surveillance (or other service with a continuous data feed) is to be supported then the deployment plan should maintain the supply of data from adjacent lamp-posts.

5.2 Stage 3

5.2.1 Functionality

5.2.1.1 Data connection - front-haul and mid-haul networks

RRUs hosted on lamp-posts act as micro-cells which are suitable for a coverage area radius of 50 to 200 metres, while RRUs hosted on lamp-post acting as mini-macro cells could cover an average area radius of 100 to 500 metres.

Data connection to an RRU on a lamp-post from a BBU is, as shown in Figure 4, via:

- optical fibre cabling as a front-haul technology as either in Point to Point (PtP), Point to MultiPoint (PtMP) or cascading the equipment using the Common Public Radio Interface (CPRI) or equivalent solution (see clause A.3);
- a mmWave (air interface) front-haul technology from an antenna connected to the BBU with a cabled mid-haul connection.

The BBU provides connection to the backhaul network. It is installed in a centralized location (see clause A.2.2) and provide service to multiple RRUs.

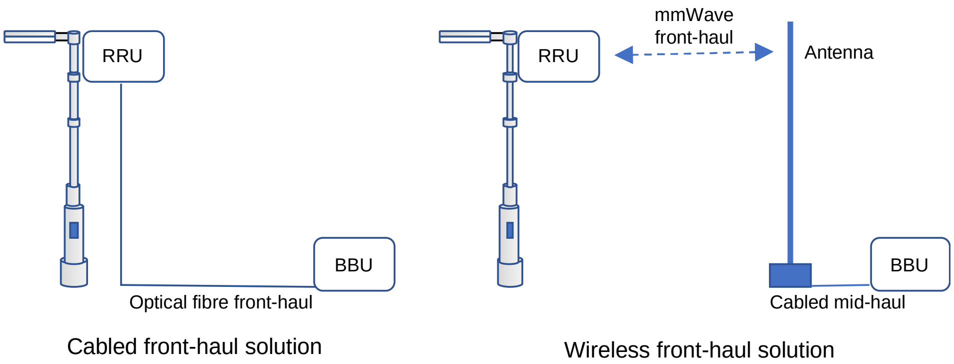


Figure 4: Data connection between BBU and RRU

Optical fibre front-haul (as shown in the schematic of Figure 5) offers the largest capacity support and scalability but requires some excavation both for data and power supply cabling unless aerial routes can be employed. The availability of existing undergroundpathways can represent a significant asset limiting the amount of excavation necessary by the Mobile Network Operator (MNO).

mmWave solutions (as shown in the schematic of Figure 6) avoid the complexities during installation and operation of such fixed data cabling installations but require the installations of antennae at the BBU and RRU and also require some excavation for power supply cabling unless aerial routes can be employed. The transmission performance is determined by signal loss between the BBU and the RRU produced by trees, rain, fog, distance, snow and oscillation of the lamp-post due to excessive wind conditions.

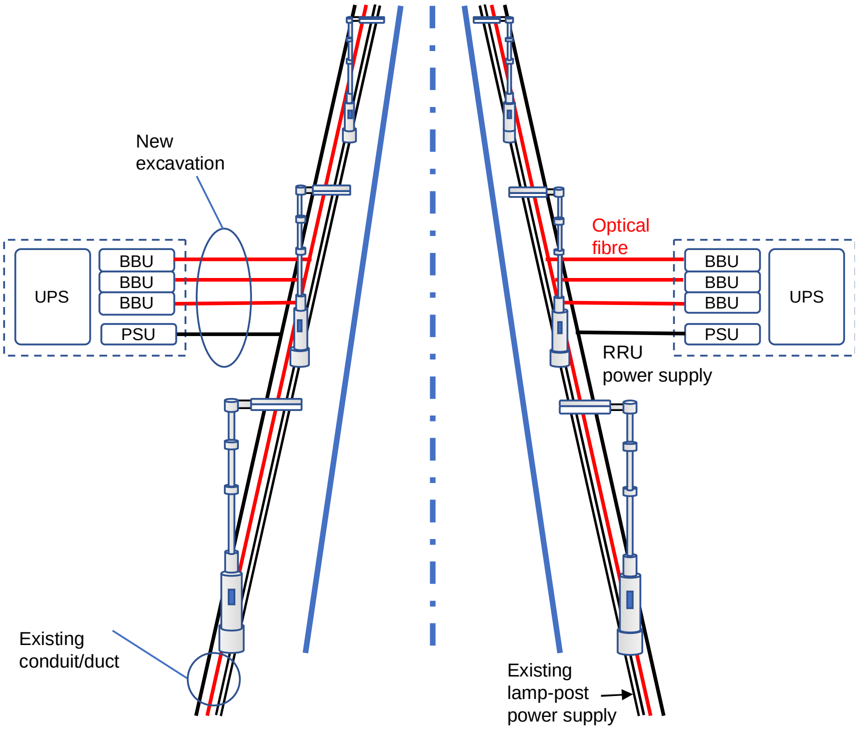


Figure 5: Schematic of separate cabled data and power supply pathways

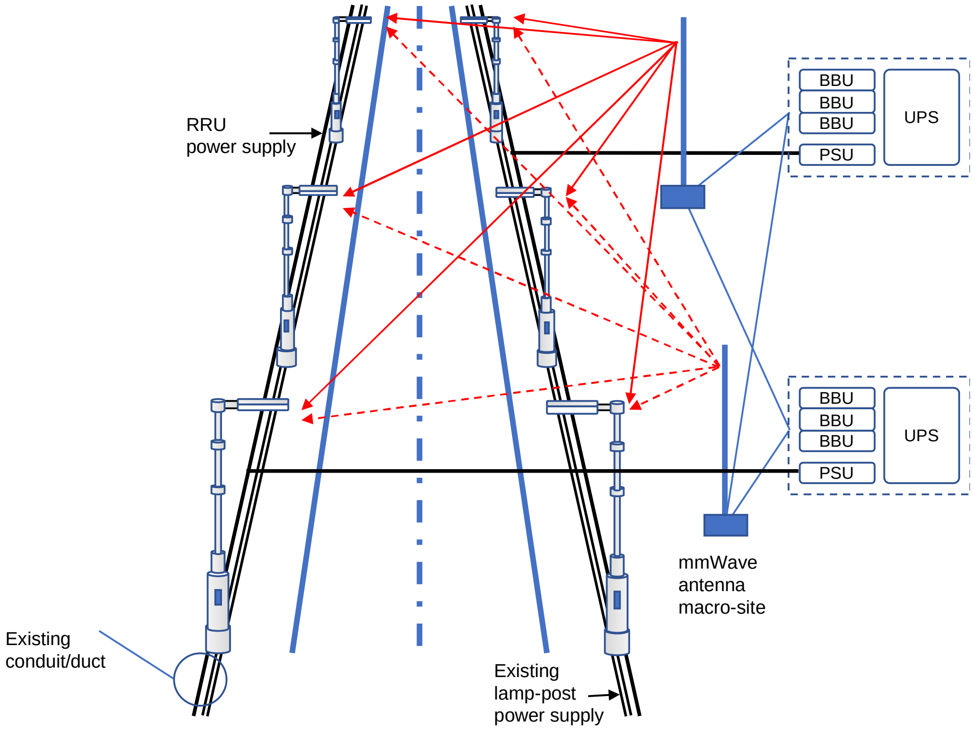


Figure 6: Schematic of wireless data and cabled power supply pathways

5.2.1.2 Power supply

Independent of the means of delivery of data to the RRU, each RRU requires a power supply. This has to be separate from the power supply to the lamp-post to support the lights and the sensor electronics of clause 5.1. This segregation is critical to ensure that any maintenance or breakdown of a lamp-post will not affect the 5G network service continuity.

Some excavation, independent of the front-haul technology applied, is required to ensure the provision of an adequate power supply (see Figure 5 and Figure 6).

5.2.2 Availability

5.2.2.1 General

The first element of availability to be addressed is the physical capability of the population of lamp-posts in a given city to support the mass of an RRU. It is recognized that not all light fittings are accommodated on street-mounted lamp-posts as shown in Figures 5 and 6 of the present document and some will be attached to, or suspended between, buildings and other structures.

While the present document does not specify the physical characteristics of the RRU, it is probable that the mass of the RRU (typically in the range 5-20 kg), will be greater than that of any Stage 2 sensor implementation. Annex A provides information on the options and trade-offs RRU for re-distributing the processing electronics of the RRU which can reduce the mass of the RRUs.

The overall availability of service provided to a given EU is a combination of the availability of the data connection and the availability of power supply to an RRU or a group of RRUs.

The availability, and quality, of power from the utility grid fed directly to a lamp-post is unlikely to be adequate for the provision of 5G services. Indeed, it is at times of failure of the grid power supply that the services provided by the 5G network are of critical value.

Unless proper powering and connectivity architectures are implemented, a single point of failure (such as damage to a connectivity or powering pathway caused by civil works on the road) can cause a widespread loss of service to multiple RRUs.

NOTE: The following explains why a direct power feed (i.e. without redundancy) would not be acceptable:

For eMBB services, overall availability will be required to be in excess of "three nines" or 99,9. This equates to 31 536 seconds of downtime per year. This can be misleading since such downtime can be one period of 526 minutes of service failure or 100 periods of 316 seconds.

As an example, if a failure of power supply to the RRU of 1 second could result in shutdown and the additional time for the RRU to recover its intended functionality was at least 5 minutes then only 105 power outages per year would result in failure to meet the overall availability of 99,9. This would require the availability of the power supply to be a minimum of 99,99997 (i.e. better than "6 nines").

For URLLC services, such as autonomous driving, overall availability will be required to be in excess of "six nines" or 99,9999. This equates to 31,5 seconds of downtime per year. If the additional time for an RRU to recover its intended functionality was at least 5 minutes then no power outages could be allowed i.e. the power availability would have to be 100.

It is therefore necessary to consider the provision of redundant architectures including:

- service to EUs using groups of RRUs fed from multiple BBUs;
- power supplies to the groups of RRUs from different sources;
- local back-up power to the RRU, dependent upon the type of power supply implemented.

The demand for increased levels of availability of both data and power supply can be enhanced by implementing a ring approach to increase the diversity of connection as shown schematically in Figure 7. This reduces the risk of disruption due to accidental damage to any one of the pathways comprising the ring.

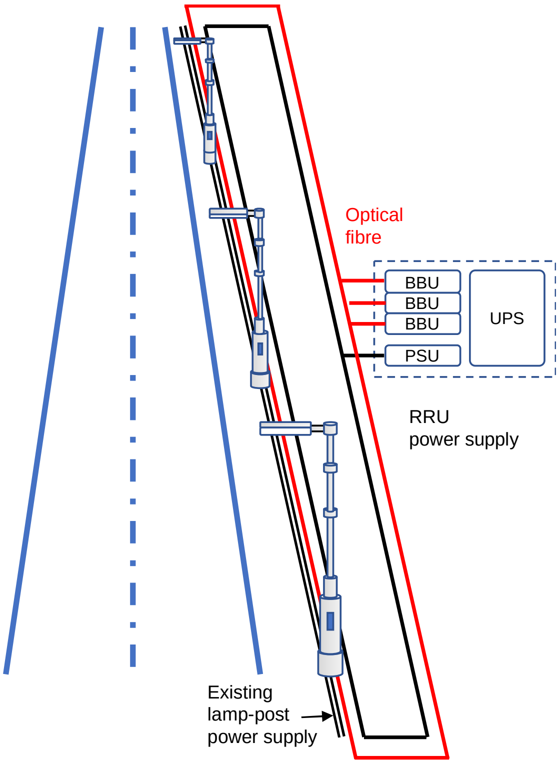


Figure 7: Schematic of ring implementation of data and cabled power supply pathways

5.2.2.2 Data connection

Examples of redundant data pathways are shown in Figure 5 where adjacent RRUs being fed from different BBUs and Figure 6 where each RRU is fed by multiple mmWave antennae (also served by multiple BBUs).

Both solutions are enhanced using the applicable ring structure of Figure 7.

5.2.2.3 Power supply

The provision of a power supply to the many RRUs in a reliable and cost-effective way is a major challenge.

Figure 5 and Figure 6 show the RRUs on each side of the road being fed by separate power supplies from the two BBU networks. It should be noted that centralized power supplies could also be accommodated in other ad-hoc sites where required due to the topology, availability of cabling and/or the reduction of the losses within the power supply infrastructure.

Both solutions are enhanced using the ring structure of Figure 7.

Independent of the power supply implemented it is important that a local overload does not cause a loss of power supply to other equipment.

Clause 8 describes alternatives for the supply of power to RRUs but it is clear that:

- the reliability of power and the power quality supplied by the grid will be inadequate in most cases;
- the installation of local battery based on Uninterruptable Power Systems (UPS) for an individual RRU will be problematic due to the size, weight and difficulties of obtaining relevant permissions - and have associated risk of theft and vandalism;
- the installation of larger items of local back-up power such as diesel generators for groups of RRUs will be problematic due to public concerns regarding pollution and noise - and have associated risk of theft and vandalism.

With regard to BBUs, the cluster approach adopted in Figure 5 and Figure 6 infer larger facilities which could adopt both battery- and generator-based UPS which can be protected against the risks of theft and vandalism by, for example, hosting them in a Central Office or equivalent structure.

6 RRU infrastructure

6.1 General

As shown schematically in Figure 8, the principal components of the RRU are the power supply converter, the Power Amplifier (PA), Radio Frequency (RF) transceiver and the antenna.

Figure 8 shows the implementation for cabled front-haul technology (as discussed in this clause) and includes the opto-electronic convertor. A mmWave technology implementation replaces the opto-electronic convertor with an additional antenna and a mmWave converter.

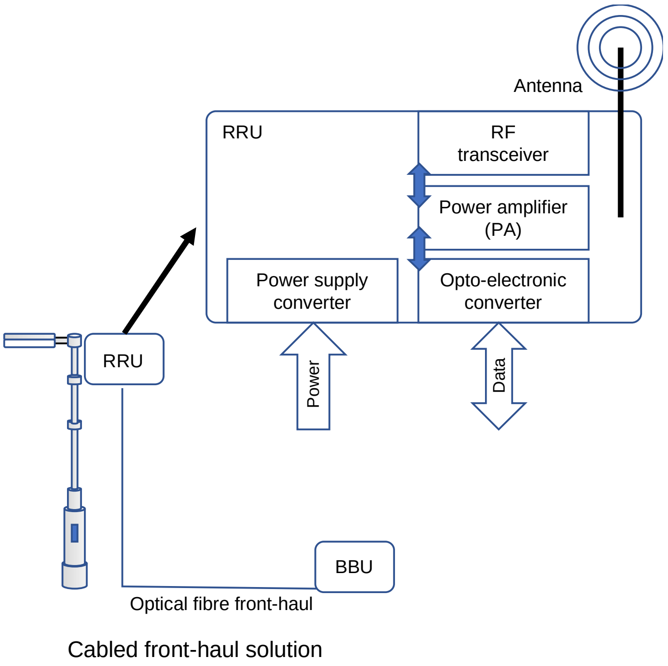


Figure 8: RRU architecture using optical fibre front-haul technology

6.2 Power supply converter

The power supply converter adapts the input power provision to the needs of its electronic circuitry.

It includes any needed AC-DC and DC-DC electronics and incorporate overvoltage protection against induction from lightning strikes in the vicinity.

6.3 Power amplifier

The PA amplifies the electrical signals received to/from the opto-electronic converter before passing them from/to the RF transceiver. It also amplifies the signals coming from the RF transceiver before transmitting them to the air interface by the antenna.

6.4 RF transceiver

RF transceiver consists of an intermediate frequency and baseband interface and the following functions:

- modulation/demodulation of the signals;
- Voltage Controlled Oscillators (VCO) and mixers;
- digital to analog conversion;
- analog to digital signal conversion;
- low noise amplifier (gain, clock, etc.).

7 RRU Installation

7.1 General

This clause describes an RRU installation mode and lamp-post design requirement, for mounting an RRU. It also defines the mechanical interface and adequate load abilities on the lamp-post migration project. When planning to mount an RRU, the lamp-post should be evaluated on a series of indicators, for example wind load, snow load, ice load, etc., to ensure the safety of a lamp-post when there is extreme weather such as strong wind, earthquake, etc.

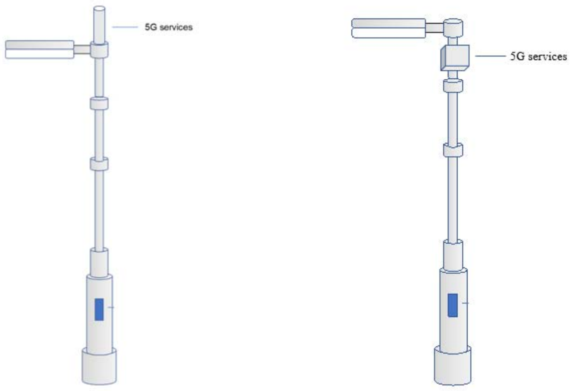
As shown in Figure 9, the typical installation modes are top-mounted and side-mounted. The mounting height should not be less than 2,5 m to optimize antenna coverage, and the minimum wall thickness of a lamp-post is 4 mm to avoid any physical security risks to the installation.

Local earthing through earth eletrodes could be installed among the protection measures against excessive main leakages from the equipment (in case of fault). It applies to Safety Class I equipment. The use of safety Class II (double insulation) equipment typically allows avoiding need for local earthing.

Overvoltages, due to induction from lightning strokes in the vicinity, can reach the equipment through the powering wiring or the backhauling connection. So there is the need to protect opportunely the equipment. As good (low resistance) earthing may not be available due to cost and operational issues, solution for protecting the equipment are both the use of transversal (wire to wire) protection circuits (e.g. GDT, Trisil, Transil, Tranzorb), together with the increased resistibility to overvoltages to the input citcuits of the equipment.

Within the range of ±60° in the horizontal direction and ±30° in the vertical direction of the RRU antenna normal line, and within 2 m from the radiation direction of the antenna, metal shielding should be avoided as it would affect adversely the RRU radio coverage.

In some cases, two or three RRUs can be mounted on a lamp-post as needed after evaluating the feasibility.



Top-mounted RRU installation Side-mounted RRU installation

Figure 9: RRU installation modes

7.2 RRU top-mounted installation

The RRU top-mounted installation can have a mechanical flange interface reserved for connection to the 5G RRUs along with the lamp-post migration project (as in clause C.1). It should guarantee adequate wind load resistance ability, together with other indicators, to ensure the safety of lamp-post when there is extreme weather. The flange should support 360 °horizontal rotation adjustment for changing RRU coverage direction according to the network deployment requirements.

7.3 RRU side-mounted installation

The RRU side-mounted installation can directly fit on existing lamp-post(as in clause C.2). It requires evaluating the feasibility of drilling holes (typically the diameter is 20 mm) for power cables and optical fibres, to enable provision of RRU's cables and fibres through the inner of the pole. Otherwise cables and fibres can be installed externally to the pole through hose clamps, but such solution could be sub-optimal due to its visual impact and the reduced robustness. In addition, the mounting kits for installing RRUs can support angle adjustment to optimize coverage.

7.4 Cover and concealing Box

A cover can be designed for mounting multiple RRUs (e.g. 2 RRUs on one lamp-post) and to protect the antenna from external mechanical stresses that could come from branches of trees in some scenarios. Additionally, the cover could provide concealment to the RRU and give mechanical protection. The design of the concealing box can be complex as it needs to satisfy challenging factors (e.g. heat dissipation, waterproof, reduced size). Furthermore, it is adding weight and wind related stresses to the lamp-post body. So, if there is no higher mechanical protection or concealment demand, it could be convenient directly mounting the RRU to the lamp-post.

The cover should be coordinated with lamp-post and allow flexible adjustment of the RRU's coverage angle. It should use non-metallic materials to avoid signal shielding and its colour should be consistent with the lamp-post. It should be designed to grant sufficient heat dissipation. Waterproof design should be considered as well.

8 RRU energy consumption

8.1 General

The micro-cell concept as implemented by RRUs hosted on lamp-posts, with support of Multiple Input-Multiple Output (MIMO) technologies, can have typical energy consumptionin excess of 100 Watts. The mini-macro cell as implemented by RRUs hosted on lamp-posts, with identical MIMO technologies, can have typical power consumption about 400 Watts. However, this is not a universal requirement and depends upon the specific implementation of the RRU by the MNO. With the development RRU solutions, lower power consumptions can allow a wider range of remote powering options (technologies and costs) to be considered.

This level of energy consumption allows fresh air cooling without the need for any active measures. This will allow reducing the energy use, the size and weight of the RRU and will avoid acoustic nois that could annoy people living in the vicinity to the lamp-post.

8.2 Power supply converter

An AC-DC or DC-DC voltage converter is required to provide the necessary voltage supplies to the RRU components. The power supply converter protects the RRU from any overvoltages due to induction from lightning stroke in the vicinity. As good (low resistance) earthing may not be available at all lamp posts due to cost and operational issues, the power supply converter could be required to implement reinforced isolation, adequate for Overvoltage Category IV (8-10 kV and combination test wave 1,2/50 µs).

8.3 Opto-electronic converter

The opto-electronic converter provides:

- opto-electronic conversion: optical signals from the front-haul connection to electrical signals for processing by the PA;
- electro-optic conversion: electrical signals from the PA to optical signals for transmission to the BBU.

Several factors will influence the optical transceiver operation such as the technology used, the required output power and the operating condition.

8.4 Power amplifier

Modelling the energy consumption of a PA is based on the following parameters:

- output transmitted power of the antenna;
- output power of the PA;
- the share of maximum bandwidth, that an antenna uses, i.e. the actual number of the physical resource blocks that occupies a certain bandwidth for transmission.

The PA is the primary energy consumer.

Generally, PAs have low efficiencies in the range of antenna transmission powers and high frequencies (many GHz) employed for the micro-cell application of 5G networks.

8.5 Antenna

The antenna does not influence directly the energy consumption as it is a purely passive element. It affects it indirectly as, depending from the antenna characteristics (the antenna gain and radiation pattern) more or less transmit power could be required. The antenna can be integrated into the RRU.

Further consumption could be required in the case of support of Multiple Input-Multiple Output (MIMO) technologies.

9 Power supply provision

9.1 Power from the grid

Figure 5 and Figure 6 show two separate power supplies feeds on each side of the road in order to reduce the risk of service disruption due to failure of one set of RRUs.

With the development of 5G aiming at easy deployment of wireless networks, the mainstream 5G related RRUs typically can support AC or DC power feeding. For most MNOs, obtaining an AC power supply from the grid is the most obvious and apparently simple solution for powering the RRU. Power from the AC grid is not able to support services requiring high availability (e.g. the URLLC services), so their delivery will require more resilent powering solutions (e.g. adding energy backups or ad hoc DC remote powering).

Certainly, the large mass 5G RRU mounted on the lamp-posts require important planning and project management because:

- the installation of such power supplies from the grid to all the lamp-posts represent a large undertaking by the responsible utility;
- obtaining a grid connection from existing buildings and getting municipal approval for hundreds or thousands of installations means negotiations with owners, tenants and suppliers;
- connecting the lamp-post to the nearest point of access to the grid may require extensive digging, implying high costs and disturbance to traffic and the population in general.

Enclosures have to be installed to accommodate the connection to the grid, metering and protection elements and in all cases the delays in power provisioning cannot be underestimated.

Continuity of grid supply can be interrupted by:

- technical influences by other third parties;
- lightning (causing protection switches to trip);
- extreme events such as floods, storms etc. which can cause disruption to telecommunications service provision at a time when it is most needed by the community and public services.

Furthermore, grid supply normally suffers severe and short-term outages and variations of supply voltage which can disrupt the function of the RRU. As mentioned in clause 5.2.2.1, they can cause the equipment within the RRU to reboot, negatively impacting to the QoS required.

As mentioned in clause 5.2.2.1, the reliability and power quality from the grid is unlikely to be adequate for RRUs when they are supporting URLLC services. In such case it would require MNOs to solve the issue by equipping each RRU with battery-based UPS on the lamp-posts in urban locations or to provide powering through ad hoc remote powering solution.

9.2 DC power feeding from centralized sites

9.2.1 General

Figure 5 and Figure 7 show the use of data and power supply cabling serving each lamp-post. The data and power are served from centralized locations co-located with the groups of BBUs. It should be noted that centralized power supplies could also be accommodated in other ad-hoc sites where required due to the topology, availability of cabling and/or the reduction of the losses within the power supply infrastructure.

This allows any battery or generator-based UPS equipment to be co-located with the power serving equipment offering potential cost and management advantages.

In all cases, it has to be assumed that the power cabling (dedicated or hybrid with data circuits) is a new installation and does not re-use any existing infrastructure. The pathways are discussed in clause 9.

There are number of power supply solutions which could be used using Low Voltage Direct Current (LVDC) rather than AC feeding. This could simplify the power conversion circuitry within the RRU (see clause 6.2). These are discussed in the following clauses. When applying remote powering techniques, appropriate protection is required to protect the telecommunications equipment against voltage surges and overvoltages on the power supply circuits caused by external events (e.g. lightning strikes in the vicinity).

9.2.2 Remote powering at 38-72 VDC

The equipment of the RRU is designed to work with the most common powering architectures found in Central Offices to supply Network Telecommunications Equipment (NTE) with operating voltages in the range 38-72 VDC.

Feeding DC voltages within such range enables the use of common and lower cost equipment. The use of voltages below 60 VDC incurs less demanding safety requirements and eases installation and maintenance.

However, within legacy telecommunications cabling, the need to limit the power losses resulting from the relatively high currents required restricts this type of solution to maximum distances in the range 200-300 m.

9.2.3 Remote powering in accordance with IEEE 802.3 applications

Sometimes referred to as Power over Ethernet (PoE), IEEE 802.3bt [i.5] specifies remote power feeding over 2 and 4 balanced pairs of cables of Category 5 and above (as specified in EN 50173-1 [i.1]). In addition, IEEE 802.3cg [i.6] specifies remote power feeding of a variety of 1 pair balanced cables. Both implementations use voltages of below 60 VDC.

Whereas the power feeding of IEEE 802.3bt [i.5] provides up to 71 W at the remote equipment using 4 balance pairs, the maximum transmission distance is only 100 m.

By comparison, IEEE 802.3cg [i.6] is specified to deliver:

- 14 W at 300 m and 2 W at 1 000 m using conductors of 0,51 mm diameter (24 AWG);
- 14 W at 1 000 m using conductors of diameter of 1,6 mm (14 AWG).

This may offer opportunities for the direct supply of power to the RRU from the BBU sites.

The technology can use multiple pairs to deliver more power to a device.

9.2.4 Higher voltage DC power feeding

9.2.4.1 RTF-C and RFT-V

Recommendation ITU-T K.50 [i.9] specifies the operation of remote power feeding of telecommunications equipment using voltage- (RFT-V) and current-limited (RFT-C) solutions capable of supplying up to 100 W per powering circuit in accordance with IEC 62368-3 [i.4].

Both RFT-C and RFT-V can use multiple powering circuits to deliver more power to a device. RFT-V can utilize multiple copper pairs in each circuit to reduce power losses.

9.2.4.2 Other solutions

A number of solutions exist where the power supply is implemented using conductors of similar diameters to those of clauses 9.2.2 and 9.2.3 but at voltages of up to and including 400 VDC.

The simplest solution is to employ a true DC voltage of approximately 400 VDC. The background to this approach is the forecast growth of NTE in Central Offices with operating voltages of 380/400 VDC. The RRU only requires a simple DC-DC conversion to the voltage(s) required by the equipment accommodated at the lamp-post. Operation of power supply cabling at 400 VDC requires specific safety procedures to be employed during installation and maintenance.

A more complex, proprietary, solution which avoids the safety considerations mentioned above features a digital DC transmission. The power available at the Central Office is converted to a digital "signal" in excess of 300 VDC which is turned on and off at a frequency enabling detection of faults (and associated removal of power) at a timescale consistent with human safety as defined in IEC 60479-2 [i.12]. The duty cycle of the digital signal is such that the average DC voltage is approximately 240 VDC.

In both cases the higher voltage requires considerably less current to deliver the required power levels which allows the use of smaller conductors without major power losses. The true DC solution has economic advantages while the digital solution obviates some of all of the safety concerns.

9.3 Hybrid data and power supply cabling

All of the solutions of clause 8.2 enable the use of comparatively small conductors and are able to supply a variety of power levels over a range of distances. This offers the opportunity for the provision of both data and power supply elements within a "hybrid" cable construction feeding the RRUs from the BBU sites.

The alternative is to install two separate cables in the same pathways but this risks of ravelling of cables preventing maintenance of both cables.

The connection of the power supply to the lamp-post to the hybrid cable may be PtP or PtMP, in a bus-like structure, depending on the powering architecture.

The hybrid cable comprises single mode optical fibre (in accordance with Recommendation ITU-T G.652 [i.7] or Recommendation ITU-T G.657 [i.8]) to supply the data and some metallic conductors to supply the required power.

9.4 Earthing

The installation of should not assume the presence of a protective earth at each lamp-post. In addition, the presence of a protective earth may not provide an effective functional earth for any sensor circuitry of RRU equipment installed on the lamp-post.

10 Accessing the lamp-posts

10.1 Existing pathways

10.1.1 General

Civil works represent the majority of the cost of deploying a telecommunications communications network outside buildings. Excavation to install new pathway systems (conduit, etc.) and cables is not only costly but can also be a source of delay due to difficulty in obtaining the necessary permissions and the resulting operational restrictions to avoid disruption to traffic and the general population.

The availability of existing pathways, underground or overhead, that accommodate the existing power supplies to lamp-posts, provides an opportunity for shared use, enabling lower cost deployment for MNOs and economic opportunity for cities to offer the available real estate for rent or lease to the MNO.

Installation and operational solutions are required to guarantee the coexistence and safeguarding of the cables (both data and power supply) of the telecommunications network and those of the existing lighting infrastructures.

10.1.2 Underground services

Underground cable management systems providing the existing power supplies to lamp-posts are typically conduits (ducts) of 80-100 mm diameter and these are frequently under-utilized, containing only one or two power circuits. The use of free space in such conduits (ducts) for the provision of data and power to support the RRUs would simplify and significantly increase the pace of 5G deployment.

However, there is a risk of cable damage to both the existing and new cables and agreement would have to be reached between the parties involved. Safety concerns can arise for MNOs when accessing assets where lamp-post powering is present or, conversely for those managing the lighting circuits that would access assets where data and power supply cabling is installed. Such safety concerns could be mitigated by appropriate segregation.

A rered way to segregate is through the installation into the existing conduits of sub-conduits (as shown in Figure 9) dedicated to the 5G power supply (and data if used) cables. The sub-conduit provides the segregation for the Low Voltage (LV) cables of the existing lighting circuits in accordance with national implementation of the HD 60364 series standards [i.3].

Figure 9: Installation of sub-ducts to provide segregation

The sub-ducts should be routed to maintenance holes dedicated to the telecommunications infrastructure.

This approach enables installation of the RRU cables when needed, without requiring multiple operations on the assets, with huge benefits on flexibility, overall reliability and costs.

10.1.3 Overhead services

Existing aerial cabling pathways serving the lamp-posts could accept the addition of data and power supply cables feed the RRU.

EN 50174-3 [i.2] specifies requirements of the installation of aerial cables on shared infrastructures.

10.2 New underground pathways

EN 50174-3 [i.2] specifies the depths of underground pathways for telecommunications cables in footpaths and roads (including parking areas). In addition, EN 50174-3 [i.2] states that installation of cables at depths less than those specified results in those installations being treated as sacrificial (i.e. subject to heightened risk of damage by other service providers).

However, the requirements and recommendations of EN 50174-3 [i.2] are always subject to local and national regulations which amend these depths.

The installation of new underground pathways requires detailed knowledge of the underground environment relating to other services in order to minimize contractual risk.

Annex A (informative): The evolution of Radio Access Network architectures

A.1 Introduction

This annex describes the evolution of Radio Access Network architectures to support the next generation of mobile networks. These details are primarily in the domain of the MNOs and are not directly within the scope of the present document. However, the information may be helpful to understand the consequences of such evolution on community infrastructures such as lamp-posts which will be critical to maintain network provision to the EU.

Existing 4G RAN architectures are mainly based on Base Station (BS) connected via optical fibre cabling or wireless links to the core network at a Central Office as shown in the schematic of Figure A.1. The BS hosts the antenna, the RRU and the baseband section dedicated to signal processing (the BBU).

The connection between RRU and baseband components is commonly referred to as front-hauling to differentiate it from backhauling, which is the connection from the BS to the core network.

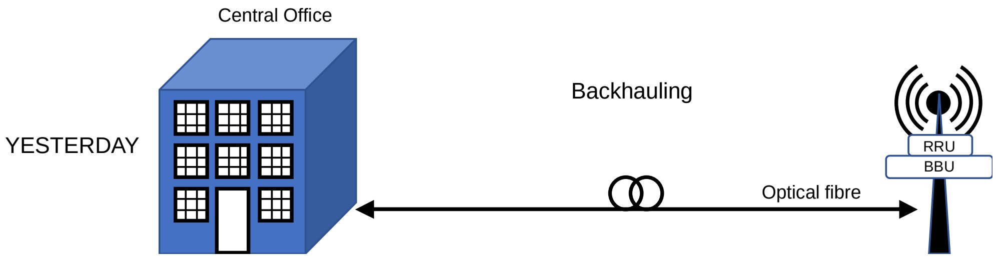


Figure A.1: Traditional RAN (distributed BBU architecture)

A.2 Centralized and virtual Radio Access Networks

A.2.1 General

Clause A.2.2 describes a Centralized RAN (C-RAN) architecture which is already used (although not at a large scale) in existing 4G installations.

Clause A.2.3 describes a Virtual RAN (V-RAN) architecture. The majority of MNOs consider that the future 5G architecture will differ from the 4G approach and will be based on Virtual RAN (V-RAN) solutions.

A.2.2 C-RAN

C-RAN solutions divide the BS functions by moving the BBUs to an appropriate centralized location (e.g. Central Office) as shown in the schematics in Figure A.2. The BBUs, in addition to being centralized, are designed to coordinate with each other, in order to optimize the performance of the access network.

This results in the BS being simplified and only containing the RRU.

The BBU and RRU remain as dedicated NTE, provided by telecommunications vendors.

The pooling of BBUs in a centralized location present several operational, hardware and spectrum efficiency advantages:

- installation is simpler and quicker and with a reduced footprint by the use of small RRUs;
- energy consumption is reduced by avoiding the losses introduced by coaxial feeders between the antenna and the RRU and the fact that cooling is no longer needed for antenna sites;

- availability of the BBUs is improved by the UPS and other back-up power provision at the Central Office.
- radio performance is improved due to the very low latency in the protocol between the co-located BBUs enabling higher capacities and improved cell performance;
- data overhead is reduced by avoiding the secured protocols on the backhaul from the BS to the Centrals Office.

In addition, pooling of BBUs simplifies network management and upgrades while reducing troubleshooting and maintenance costs due to a reduction in BS visits.

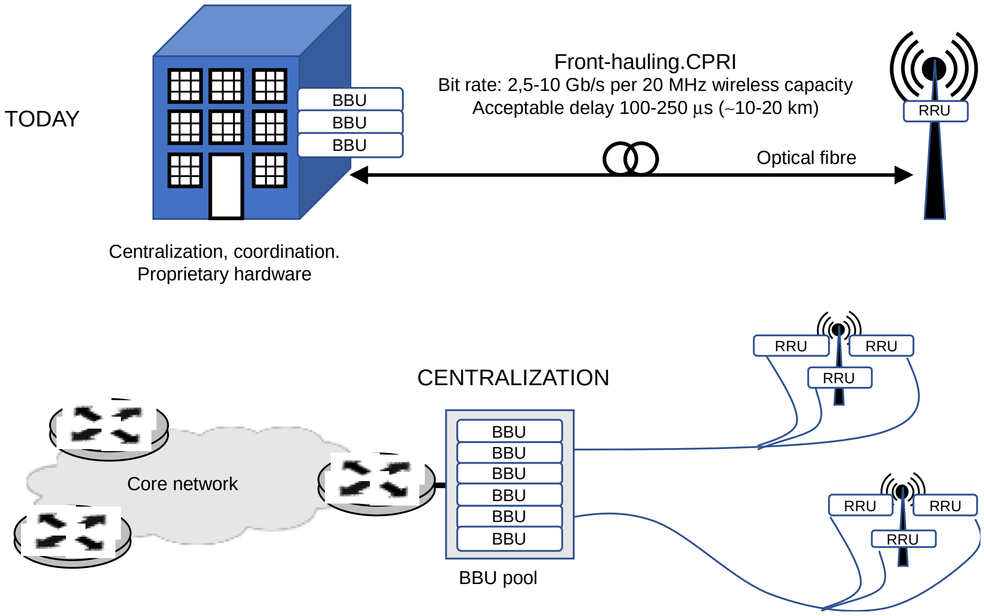


Figure A.2: C-RAN and traditional front-hauling architecture

A.2.3 V-RAN

In the case of V-RAN as shown in Figure A.3, the BBU functions will be performed by software on generic Information Technology (IT) server equipment using the same rules and same processes as those currently existing in IT data centres. This migration to software-based solution is generally termed Network Functions Virtualisation (NFV). V-RAN builds upon the advantages of C-RAN by introducing more efficient front-haul technologies to limiting transport investments (substantially based on Ethernet) and use of IT technologies and NFV solutions, with advantages in terms of scalability, costs and resilience.

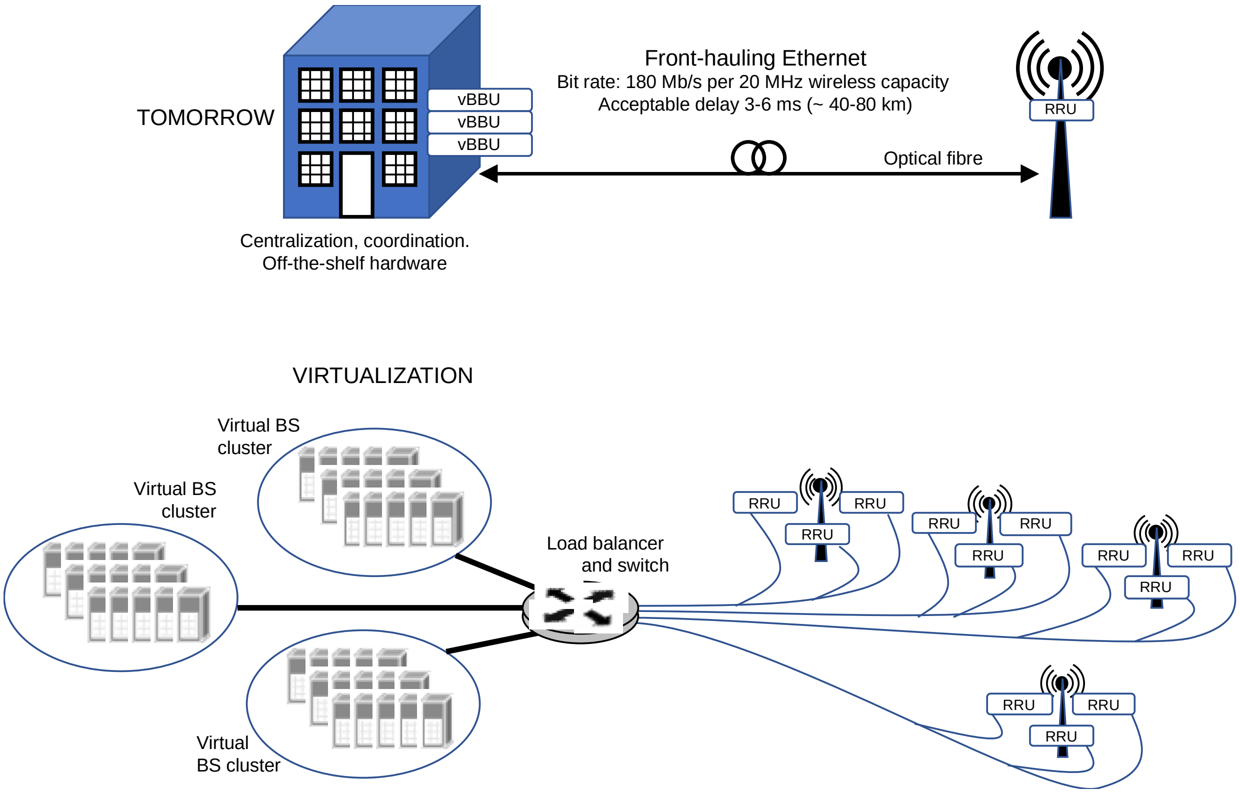


Figure A.3: V-RAN and innovative front-hauling architecture

Virtualized architectures can provide increased levels of resource sharing, agility and scalability while decreasing deployment time. Also, the use of generic IT servers to host the BS components will provide improved energy management and reduce the energy consumption.

This provides an opportunity to operate a Network Service Platform (NSP) making mobile telecommunications functions "a service" in the same way that Cloud Computing platforms do in the IT environment. Using statistical multiplexing an NSP can perform the same tasks with less and cheaper hardware.

NOTE: As an example, NFV MANO is a framework developed by a working group within ETSI Industry Specification Group for NFV (ETSI ISG NFV).

The highest degree of mutualization is achieved with a fully centralized BBUs approach because processing the lower layers in a BBU constitutes a large part of the computational effort and can be performed with specific hardware.

Further expansion of capacity can also be achieved using radio cells, creating heterogeneous networks: mini-macro cells and even small cells, for example of micro- and pico- type, can be connected to a V-RAN architecture, maintaining the benefits of coordination and optimization performance.

In this way Central Offices absorb the functions of data centres. However, for some specific applications such as URLLC, data centres will have to be located close to the RRUs they serve. In such a case, the term Multi-access Edge Computing is used

The solutions employed will be the choice of the MNO but the community infrastructure will have to provide infrastructures (e.g. lamp-posts, traffic lights, buildings, etc.) to host the RRUs. Identifying locations where to install such RRUs, together with the development of cost and functionally efficient connectivity and powering architectures, will be among the biggest challenges for the development of mobile networks.

A.3 Front-haul

As described in clause 5.2.1.1, the front-haul infrastructure can be an optical fibre connection or, under certain conditions, a wireless connection.

The choice of the technology, the protocol and the location of the different functions of the BBU (functional splits) will be the choice of the MNO and will be based on criteria such as:

- the specific use case;
- the distance between the BBU and the RRU;
- the required bandwidth;
- latency constraints;
- the impact of loss of service.

Several possibilities are existing for front-hauling - the most common solution at this time is CPRI.

In C-RAN architectures, the front-haul carries the signal between the BBU and RRU. Consequently, C-RAN architectures requires optical transport networks for carrying multi-Gigabit radio signal in real time.

In V-RAN architectures, part of the signal processing is undertaken in the RRU reducing the demands on the front-haul network. This allows consideration of mmWave solutions.

To be compliant with the latency recommendation, a passive front-haul link should not exceed a distance between 10 km and 80 km (depending on the RAN implementation as indicated in Figure A.2 and Figure A.3). The presence of active equipment within the front-haul could generate additional latencies and thereby reduce this distance.

Baseband modules and radiofrequency modules are connected via a fibre-optic connection, or sometimes, in a specially designed radio bridge, with an interface aiming to carry and reconstructing the radio signal.

Every carrier of 20 MHz of radio spectrum requires at least 2,5 Gb/s on the front-haul. There are also constraints on latency (of the order of 100 μs for C-RAN and 1 ms for V-RAN).

When MIMO techniques are used such front-haul capacity needs to be multiplied. Multi-cell and multi-frequency BS sites therefore require very high transmission capacities which make CPRI, originally defined for applications in a different context, difficult to realize an efficient 5G RAN.

NOTE: A new interface eCPRI (evolved CPRI) is now proposed defined by the IEEE Next Generation Fronthaul Interface (IEEE 1914) working group.

Research and prototyping activities are focusing on the split between BBU and RRU to determine the most efficient division of functionality to reduce bandwidth requirements (bringing them to values close to the capacity transported), and latency (in the region of milliseconds) while retaining as much as possible the performance of traditional RAN architectures.

The best functional split solutions enable high mobile network performance to be achieved by using Ethernet-based transport for front-hauling. This also supports the transition from C-RAN to V-RAN where the commercial equipment used in NFV architectures are Ethernet-based.

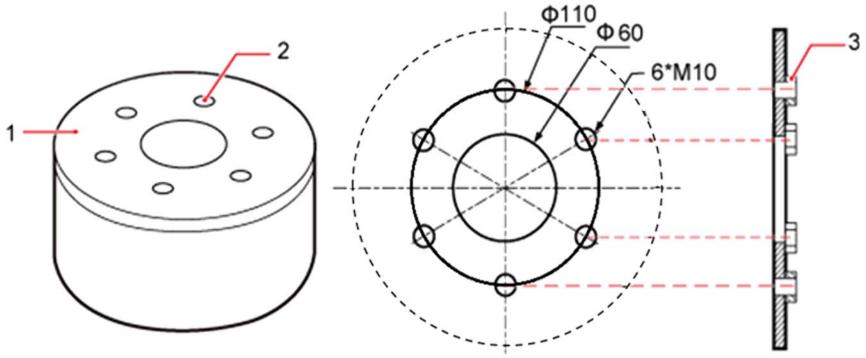
Annex B (informative): Void

Annex C (informative): Example and Interface of RRUs Installation

C.1 Top-mounted flange interface

The example of Lamp-posts mounting RRUs on top position is shown in Figure C.1. The flange interface can be reserved on the top of lamp-post. The three waist holes of the flange are connected to the lamp-post landscaping cover, to adjust the horizontal angle of RRUs inside. The typical dimensions of the physical flange interface is shown in Figure C.2, the inner diameter of the flange should be not less than 60 mm, which is convenient to reserve enough space for RRU's power cables and optical fibers distribution inside. However, the actual dimensions of the top physical flange interface should be determined according to the whole lamp-post design.

Figure C.1: Example of Lamp-posts mounting RRUs on top position



(1) Flange (2) Screw hole (3) Nut

Figure C.2: Dimensions of the flange interface

C.2 Side-mounted interface

Another position to install a RRU is on a side of a lamp-post. Such solution is normally taken either for specific aiming of the coverage area or if the shape of the lamp-post is not allowing the RRU to be mounted on top position (as in Figure C.3). The RRU side-mounted interface as shown in Figure C.4. The appropriate diameter of drilling holes is 20 mm, to enable provision of RRU's cables and fibres through the internal part of the pole. Drilling holes requires applying waterproof and anti-corrosion treatment after the RRU is mounted.

Figure C.3: Example of Lamp-posts not allowing mounting RRUs on top position

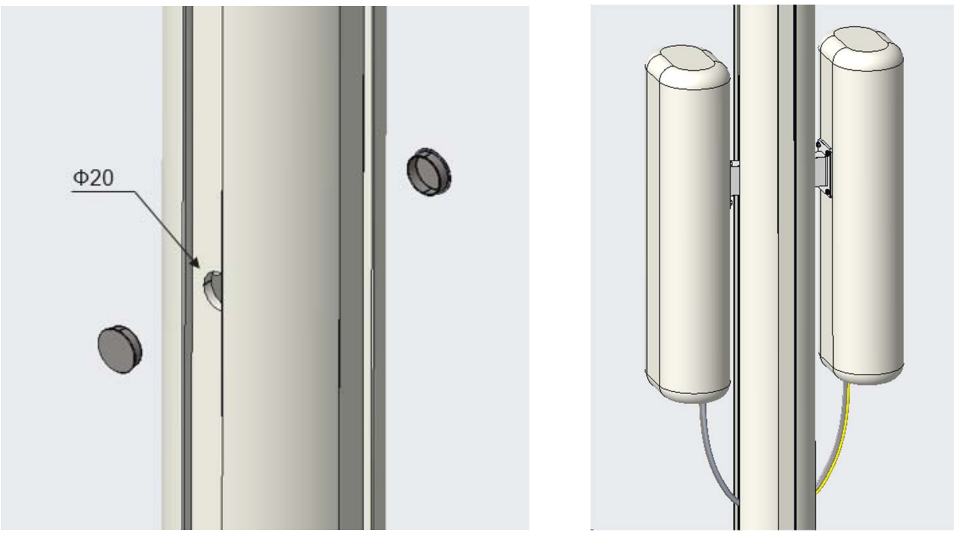


Figure C.4: Side-mounted Schematic Diagram

History

Document history		
V1.1.1	June 2019	Publication
V1.2.1	November 2020	Publication