Optically Powering the Telephone over Optical Fiber as Potential Strategy for Providing Reliable Uninterrupted Access to Emergency Service -911- at Low Cost during Lengthy Commercial Power Failures

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This contribution to the FCC Notice of Proposed Rulemaking (NPRM) " Facilitating Technology Transitions by Modernizing Consumer Protection, Competition Rules-Proposal Meant to Preserve Access to 911, Increase Transparency & Maintain Competitive Choices", addresses mainly the technical and system architecture aspects related to CPE powering and back-up power to provide uninterrupted access to emergency services – 911, whose importance to public safety and homeland security has been clearly recognized by the FCC. General network architecture is first presented to identify the regulatory interconnections impacted by technical transitions and the relevant FCC rules and regulations. A methodology is then offered that can be used to compare the power consumption of different CPEs with different functionalities and bandwidths and sets the target for CPE consumption that can be optically powered over optical fiber to provide uninterrupted access to emergency services in case of power outage for long durations. It should also offer a framework for assessing the suitability of power back-up technologies in the marketplace today and future strategies for providing back-up power from the Central Office during lengthy commercial power failures.

Background

In its Open Monthly Meeting on November 21, 2014, and the Notice of Proposed Rulemaking (NPRM) "FCC proposes Facilitating Technology Transitions by Modernizing Consumer Protection, Competition Rules - Proposal Meant to Preserve Access to 911, Increase Transparency & Maintain Competitive Choices", the Federal Communications Commission (FCC) seeks comments on modernizing its rules to ensure access to 911 service, protect consumers, and preserve competition as the technology transitions move forward from copper networks using legacy technologies to fiber, coaxial cable, and wireless networks using Internet Protocol (IP)-based technologies to carry voice, data and video.

The rules should ensure that this modernization of FCC rules will help expedite the transition to next generation networks by protecting core network values of competition, consumer protection, universal service, and public safety and national security in order to give consumers and businesses the confidence they need to embrace technological change and all its benefits.

The main areas covered by the NPRM are:

- Protecting Consumers' Ability to Call 911 during a Power Outage
- Increased Transparency to Empower and Protect Consumers During Transitions
- Preserving and Encouraging Competition

The first item concerns public safety, universal service, and protecting the consumer's ability to call 911 during a power outage**.** The second item concerns the FCC rules governing changes in service features that customers rely on to conduct their business but may not be supported following a technology transition; such as, network changes when carriers plan to shut down (or "retire") their existing copper networks. The third item concerns the FCC rules impacted by technology transition in the access network when competitive service providers may no longer be able to reach customers if carriers withdraw certain "last mile" wholesale services. The need for FCC new rules is mainly due to technology transitions.

Technology Transitions Drivers: In general, the driver for a technology transition in a functioning marketplace can be one of many that might benefit one or more market players. The drivers can be: new profitable service, new revenue stream, cost reduction, competition, regulation/policies…etc. However, in the case of a non-functioning market, where competitive market forces fail to deliver the services to the citizen, or cause market and service fragmentations and lack of interoperability, regulatory intervention might be required.

One driver for a technology transition can be to offer incrementally higher bandwidth services over the same infrastructure. Figure 1 shows the bandwidths of the different electronic communication services starting from 4 kHz for analog telephony to 24 Gbps for broadcast Super-Hi-Vision television. Figure 1 also shows the capacity of the different transmission physical media and the distances over which this capacity can be realized. The important physical characteristics of the physical layer are: bandwidth, attenuation (which determines reach), and power handling capacity (which determines possibility of remote powering the CPE for high service availability). In general, the required power to operate the electronic equipment increases with increased service bandwidth and CPE functionality.

Figure 1 shows that copper twisted pair can deliver asymmetrically 20 Mbps over a distance of 1 km and 1 Gbps over a distance of 80m using G.fast technology, while coaxial cable can deliver asymmetrically 1 Gbps over a distance of 200 m. In contrast, a point-to-point single mode optical fiber has a symmetrical capacity of more 30,000 GHz over a distance of more than 60 km. Wireless medium can also deliver high capacity; for instance 1 Gbps can be delivered over wireless LTE femtocell shared by several customers over a distance of 10m.

Methodology to Assess Feasibility of Remotely Powering the CPE For High Service Availability During Power Outage

Public Network Architecture: Telecommunication services are delivered to the end customer over public networks, regulated by the FCC, using different technologies. Figure 2 shows technologies and architecture of a national telecom network to deliver communication services to end users over different electronic communication networks. The figure shows the typical CPEs (phone, TV, PC, radio..) and mobile equipment used to support the services listed in Fig. 1. The CPE is connected to a Public Network Operator through the access network, shown in Fig. 3, using any of the physical technologies. Figure 2 also shows the carriers' networks spanning a country consisting of applications, transport and network, and physical layers. This network is used by the carrier to transport cost effectively the signal, directly or through another carrier, to another end-user who can be a residential customer or a public service; such as police, ambulance, fire service…etc. This will require well defined technical interconnections and system interoperability used by different carriers.

Figure 2 also shows that power sources are required at different locations to operate the communication system. The regulatory interface over which power is delivered to the CPE, which can be affected by technology transitions, is the "Demarcation Point – CFR 47 part 68.3"/ "Network Termination Point" interconnecting the Customer Premise (CP) to the Public Network. It determines the architectural interface and sets the functionalities of the interface and the responsibilities of the Public Network Provider/Operator and the customer.

Access Network Powering Architecture: The importance of CPE powering was learnt through the hard lessons of "natural experiments"; such as Hurricane Sandy in 2012, and the derecho in Midwest and Mid-Atlantic in 2012 when power outages lasted several days and thousands of homes were unable to access 911 emergency services when most needed.

The current different architectures for powering CPE in the public access networks are given in Table 1. Traditional phone service on copper networks works even during power outages because the copper wires are powered separately by the phone company who uses centralized powering with primary batteries, secondary battery back-up, a standby generator with fuel supply, and trained personnel to restore power quickly to connected customers in case of commercial power outage. Current fiber and cable networks have many advantages, but they use local powering which does not provide power to the handset from the communication network and during a power outage, consumers must rely on a battery back-up in their own homes. Table 1 compares the different CPE powering architectures in terms of: back-up battery location, resilience/restoration time, cost, and physical layer's technology and architecture that use the powering architecture. It is worth pointing out that reverse powering, proposed for powering G.fast CPEs, has comparable cost and similar resilience and restoration time to local powering, because the power is delivered from the customer premise.

Obviously, wireless medium can not support handset remote powering and must rely on local powering with battery back-up that needs to be recharged from a mains supply, as shown in Fig 3. However, wireless handsets supports mobility which can complement the large transmission capacity and remote CPEs powering that wireline medium can support.

General Methodology for Calculating CPE Average Power Consumption: The steps of a general methodology to calculate the power consumption of CPEs, or any other finite state system, with different technologies and implementation are:

1. Define the states of the CPE.
2. Identify the CPE physical modules (building blocks) and the functionality of each module, including the role played by the user, and their interconnection in each state
3. Map the functionality of each module of the communication system/CPE onto the functionality of an Architectural Functional Reference Model; such as the OSI, or TCP/IP (Internet) given in Fig. 4.
4. Determine the average power consumption of the modules in each state.
5. Determine the time duration of each state per day representing a realistic system utilization profile.
6. Determine the CPE average power consumption per day.

The above methodology can be used to calculate and compare the power consumption of:

- Traditional analog telephone (POTS); which should be used as the baseline.
- Analog telephone with an optical transmitter/ receiver optically powered over fiber
- Digital VoIP telephone with optical transmitter/ receiver optically powered over fiber

The states of the traditional analog telephone (POTS) are defined in the USA by the FCC regulation CFR 47 Part 68 and industry technical standards TIA 968. The regulations also specify the power consumption and signal levels in each state. The modules of a standard analog telephone are shown in Figure 5a together with the location of the regulatory "Demarcation Point" or NTP. The CPE is powered from the Central Office (CO), and should consume less than 1 mW in the Quiescent/Idle state, less than 1 W (50 V and 20 mA) in the OFF-hook Call and Dialing states, and less than 1 W in the ON-hook Ringing state. The average usage of a telephone per day is around 20 minutes. Using these numbers and assuming power consumption of 300 mW in the Call state, the average power consumption per day of a traditional analog copper-based telephone's CPE is 10 mW with electricity cost of 2 ¢ per year, which should be used as the baseline. In addition, the service availability of this system is 99.999% (five nine).

The power consumption of an analog telephone with a proprietary optical transmitter/ receiver optically powered over fiber, shown in Fig. 5b, is 4 mW per day every day for Call and Ringing durations of 24 and 6 minutes respectively, and 18 mW per day every day for Call and Ringing durations of 8 hour and 0.3 hour (18 minutes) respectively.

Similarly, the digital VoIP telephone with optical transmitter/ receiver optically powered over fiber shown in Fig 5c can be calculated using the same methodology outlined above. Table 2 gives the modules used to implement each CPE. The main difference in the power consumption of the two implementations is the additional modules required: to convert the analog acoustic signal to digital electrical signal (and back to analog acoustic signal from received digital electrical), the modules to implement IP (Layer 3) and Link (Layer 2; such as Ethernet), which will increase the power consumption of the CPE.

In general, the transition of the CPE from analog voice telephony to digital voice over IP (VoIP) in the application, transport and network layers, especially when using broadband modems, increase the CPE power consumption and might impact its ability to satisfy the regulatory requirements. This transition, driven by low telephone bill, can lead to a considerable increase in CPE power consumption, causing a change in the CPE powering architecture from centralized powering to local powering which might rely on battery backup. The current VoIP modems consume at least 1-W in the idle/quiescent state (ON-hook), compared to less than 1-mW consumed by an analog telephone in the same state. Obviously, VoIP telephone modems (CPE) must rely on local powering with battery backup in case of power outage. This transition from analog telephone CPE service with centralized powering (99.999% availability at low cost) to digital VoIP CPE with local powering with battery backup will result in lower service availability and lower network reliability and slower restorable critical communication infrastructure.

The above methodology can be used to compare the power consumption of different communication CPEs to deliver the telephone service. The results are shown in Table 3 which clearly shows that currently standardized CPEs, which are designed to deliver broadband and TV services and offer telephony as over-the-top (OTT) VoIP service, consume more power than the traditional telephone over copper system and must be powered locally with a battery back-up. This is an expensive solution that offers lower availability than the 99.999% (five nines) which copper based networks delivers.

However, it is feasible to design an optical communication system with such low power consumption that it can be optically powered over the optical fiber using centralized optical powering architecture to support "lifeline" voice universal service without using copper links or battery backup. This way, high levels of universal service availability can be achieved at cost similar to that of copper systems. This technology should enable the transition from copper to an optical fiber infrastructure offering continuously available service even during commercial power outage. This transition will enable the offering of locally powered new multi-services of very high bandwidth applications in addition to telephony, exploiting the future-proof optical fiber infrastructure of more than 30,000 GHz bandwidth, at low cost over distances of more than 10 km.

Dr. Salah Al-Chalabi has published two papers in the IEEE Communications Magazine (Sept. 2011 and Aug. 2012) on optically powering the telephone over optical fiber titled:

- "Powering the telephone over optical links for high availability, low cost, and small carbon footprint"; S. A. Al-Chalabi, IEEE Communications Magazine, Sept. 2011, pp. 48-55.
- "Optically powered telephone system over optical fiber with high service availability and low risk of investment in FTTH infrastructure"; S.A. Al-Chalabi, IEEE Communications Magazine, Aug. 2012, pp. 102-109.

In the first paper Dr. Al-Chalabi shows that, although optical power levels transmitted over optical fiber are limited by nonlinear effects and safety standards, it is feasible to power the telephone CPE optically by sending optical power over the optical fiber connection. In the second paper, Dr. S. A. Al-Chalabi described an innovative optical communications system using centralized optical powering where part of the received optical power is converted to electrical power using photovoltaic cells and an energy storage device to drive the CPE. The reach of the system can be more than 10 km, and superfast broadband and HDTV CPEs are locally powered.

Strategies for Deploying Fiber in Urban, Sub-urban, Rural, and High-cost Areas with Low-Risk Investment

The transition from copper to optical fiber in the physical layer with centralized optical powering and innovative low power consumption and low cost CPE that delivers Universal Service telephony over 10 km with high service availability, lays the foundations for high capacity (more than 30,000 GHz) network of high reliability and rapidly restorable critical communication infrastructure. The very high bandwidth of optical fiber connection provides the future-proof broadband network required by Connect America's objective and by the USF/ICC Order (2011) to connect customers in urban and rural areas, and encourages competition and innovation.

Delivering voice over fiber as a Universal Service at comparable cost with that of delivering it over copper removes the uncertainty in service take-up over fiber, and eliminates the investment risk in a FTTH infrastructure. Superfast broadband data and HDTV services can be added to this future-proof infrastructure, when requested by the customer. The lowest cost upgrade strategy is to install the “lifeline” voice system over fiber as the foundation and add the superfast data and HDTV upgrades by posting low cost, standardized “plug-and-play” CPE that can be installed by the customer with the help of technical support over the “lifeline”. This optical, future-proof infrastructure of more than 30,000 GHz over distances of 10 km, can then be exploited to deliver the very high bandwidth advanced services, which twisted pairs and coaxial cables can not deliver, with much lower power consumption CPEs and lower incremental cost and shorter provisioning time than copper-based systems.

In addition, such low power consumption optical communication systems offer not only low-cost universal services and future-proof optical broadband, but also an environmentally-friendly communication network supporting the efforts of the FCC and USA government to reduce the power consumption and carbon footprint of the communications sector.

I hope that this contribution assists the FCC in analyzing the power consumption of any CPE, and provides guidance to improving designs, standards, and input to any relevant new FCC rules. One such area might be regulatory rules and technical standards for the “Demarcation Point” (already defined for copper) for optical fiber connection. Defining this regulatory point will determine where the Universal Service is provided and whether centralized optical powering over optical fiber will be available from the Central Office. The other area might be CPE power consumption levels in each state, which is determined for traditional telephone apparatus by CFR 47 Part 54 & Part 68”. According to these standards, the telephone apparatus should consume less than 1 mW in the quiescent/idle state. However, currently standardized broadband, Ethernet, VoIP, DOCSIS, xDSL, and GPON CPEs consume more than 1 W in this idle state. It is, therefore, imkperative that the FCC should provide regulatory requirements to technical standards making bodies in the area of public communication networks to define CPE’s states and maximum power consumption in each state and ensure that equipment in the marketplace conform to those national and internal standards.

I will be very happy to provide the FCC more detailed information about possible low power optical technology which should provide uninterrupted access to emergency service over fiber at low cost. This should protect the citizen much better than currently standardized optical technologies for the access network, and provide a future-poof, high bandwidth, low cost infrastructure (more than 30,000 GHz) supporting universal services in urban, suburban, rural, and high-cost areas in the USA.

Thank you very much for your efforts and giving the stakeholders an opportunity to provide contributions in this very important area.

Yours sincerely,

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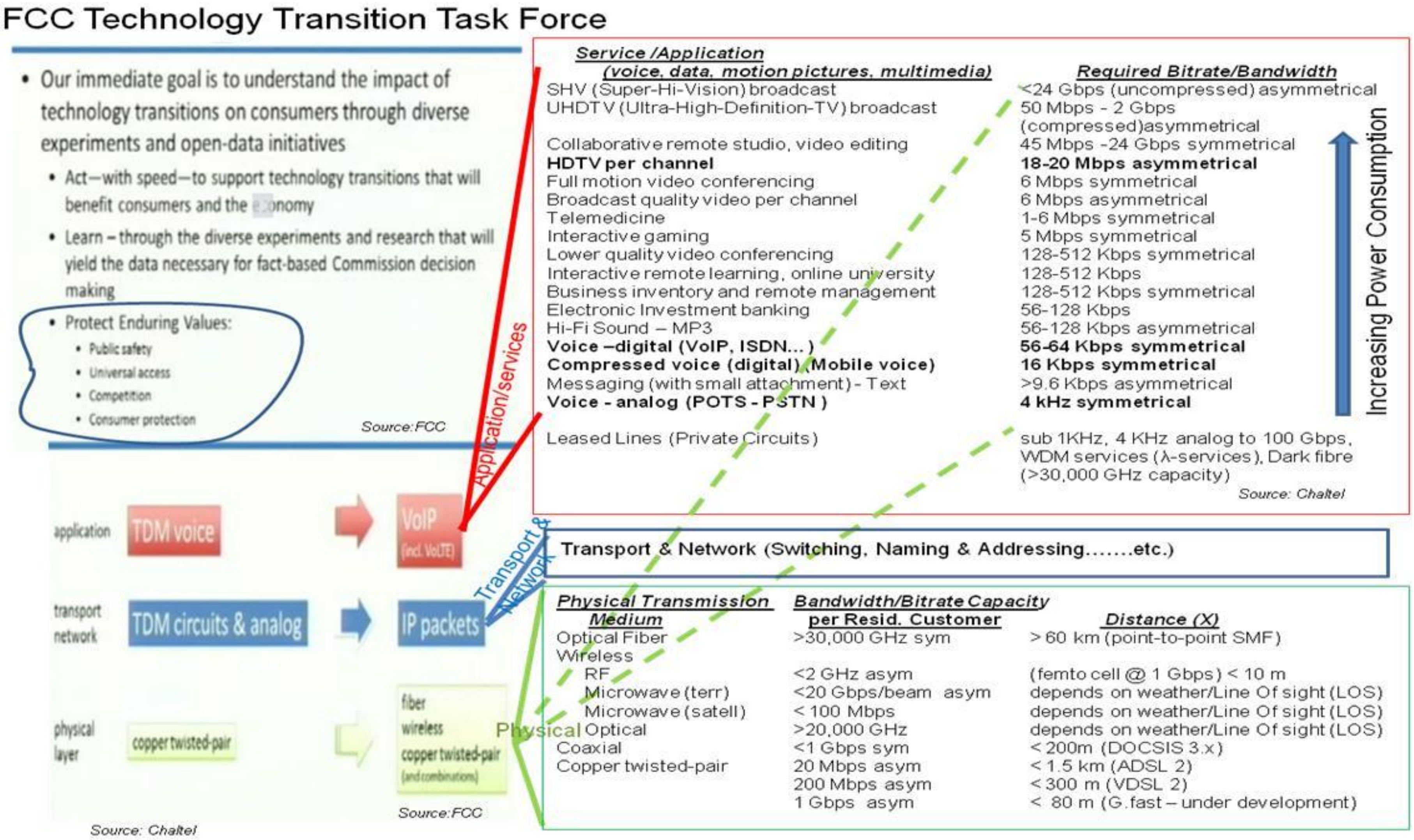

Figure 1: Framework for Mapping the Impact of Different Technology Transitions in the Different Architectural Layers onto Telecommunication Services/Applications and the FCC Network Enduring Values

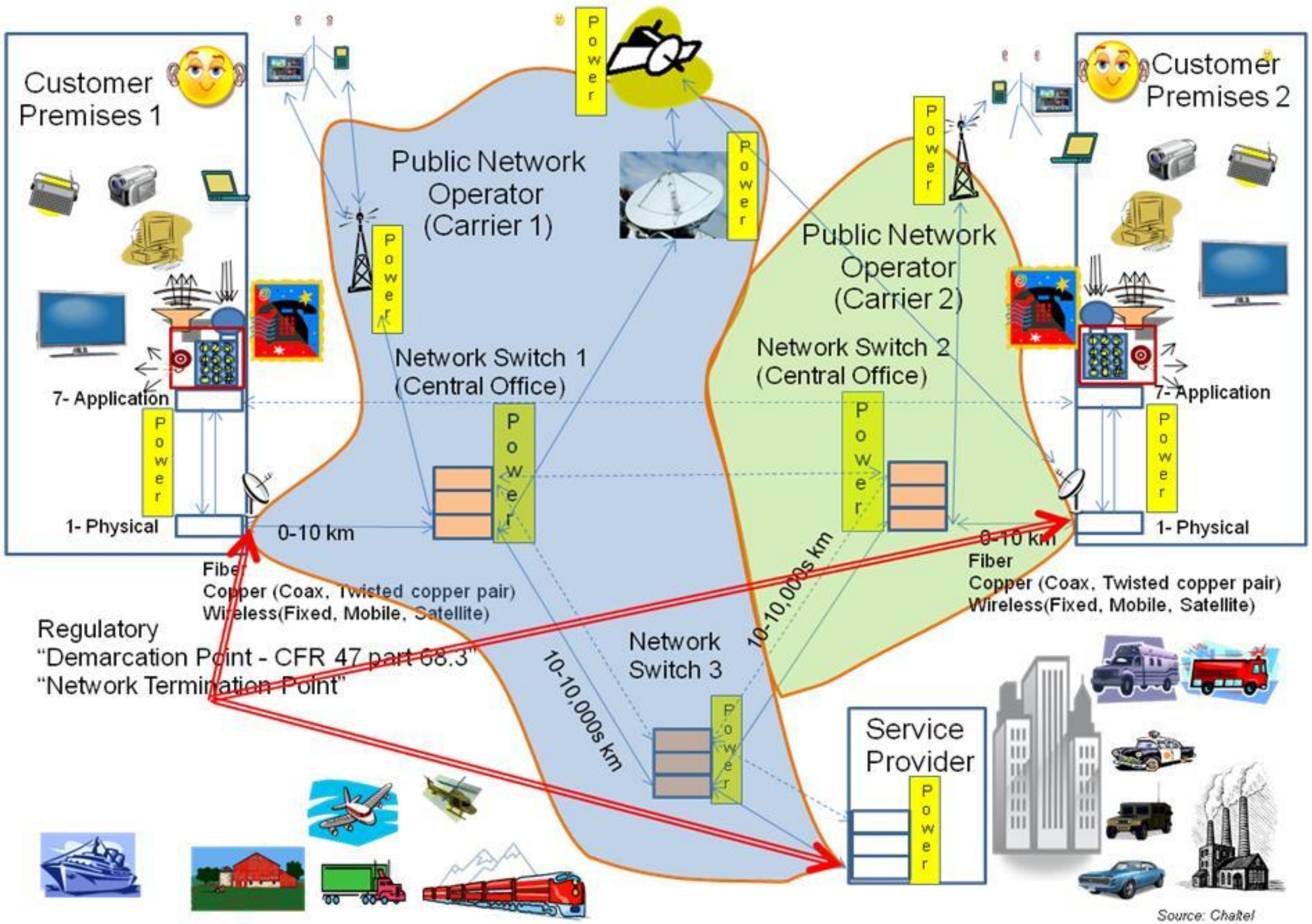

Figure 2: National and Global Telecommunication Network and Systems Architecture

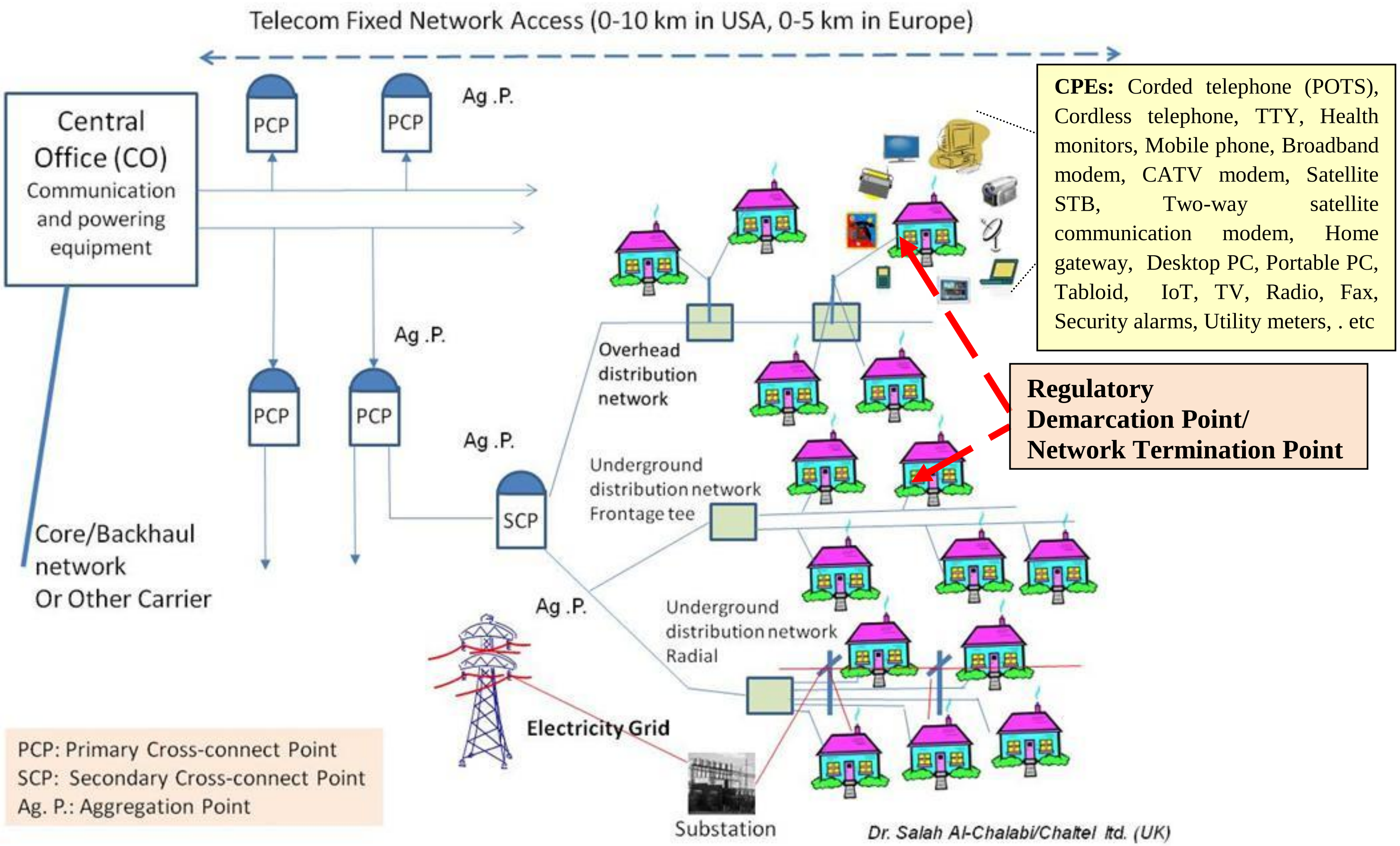

Figure 3: Telecom Public Fixed Access Network and Local Electricity Grid

Powering	Definition and main power source location	Back-up battery location	Resilience/ Restoration time	Cost	Physical Layer Technology & Architecture
local powering:	powering a telecommunications equipment by a (dedicated) power unit implemented at the CP.	CP (indoor or outdoor)	low/long	high	FTTH, Wireless (Wi-Fi, cellular, Wi-Max, Satellite set-top box, TV), CATV, VoIP (modem or Personal Computer)
reverse powering:	Power from the CP is provided to a Distribution Point (DP) outside the CP by means of a dedicated power copper line from each CP. The DP can serve one or several CPs.	DP or CP	Low/long	high	FTTC/B (evolving G.fast standard)
cluster powering:	remote powering of a cluster of equipment, in which the power source is located outside a telecommunications centre (CO).	Outdoors in - street cabinets or - underground manholes	medium/ medium	medium	FTTB, FTTC/N , CATV, wireless (base stations, satellite ground stations)
centralized powering:	remote powering in which the remote power source is located in a telecommunications centre (CO).	CO (a back-up generator can also be used with stored fuel)	very high/ short	low	Copper, FTTH (remote optical powering)

CP: Customer Premises

CPE: Customer Premises Equipment

CO: Central Office

DP: Distribution Point

Table 1: Standard Access Network Powering Architectures

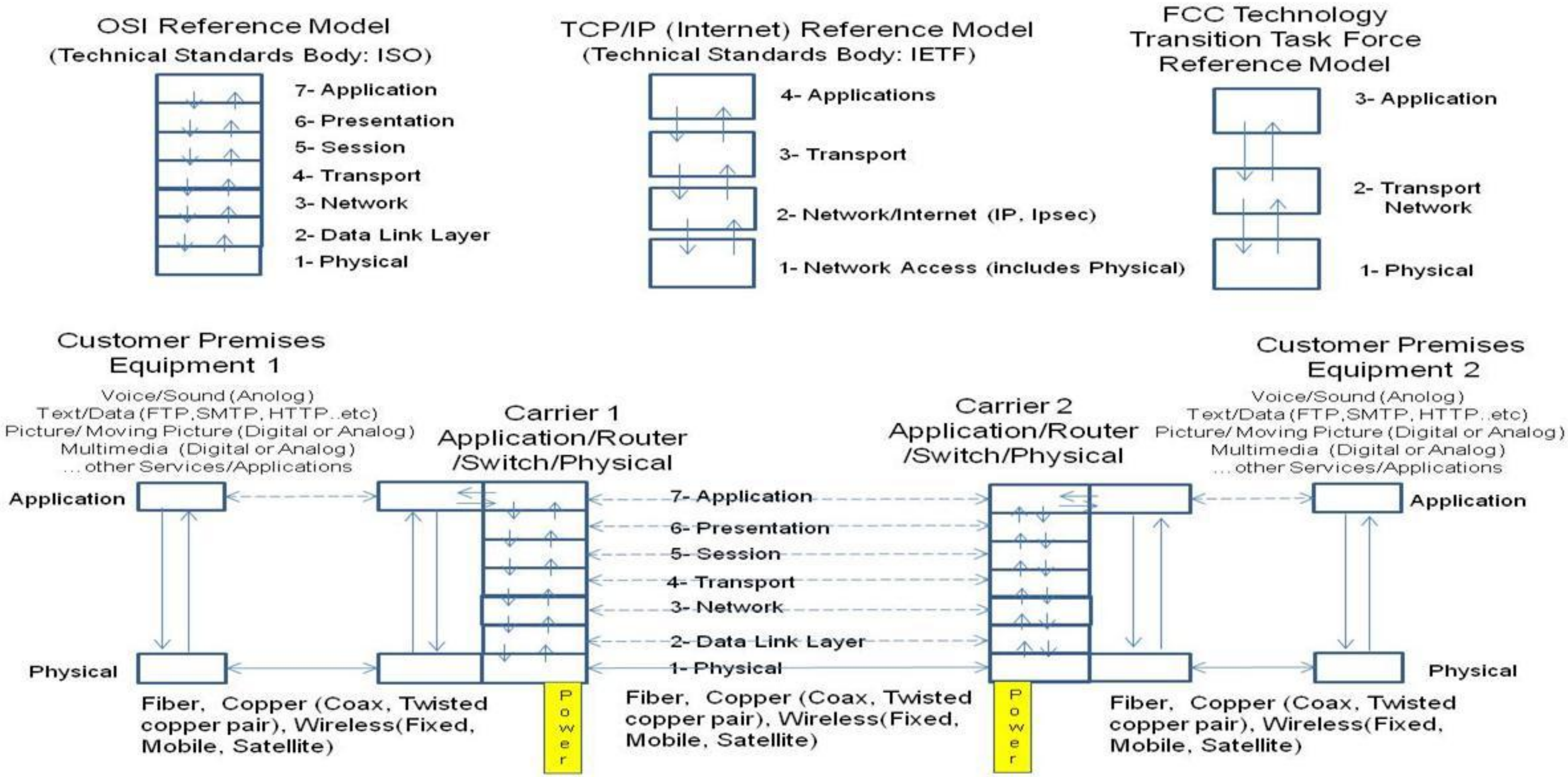

Figure 4: Top: Communication System Reference Model Architectures; Lower: Possible Implementation of a Networked Communication System with Analog or Digital Transmission between CPE and CO

Note: It is important to note that the above models are only used to help understand networked communication systems (especially digital systems or computers). Other models exist.

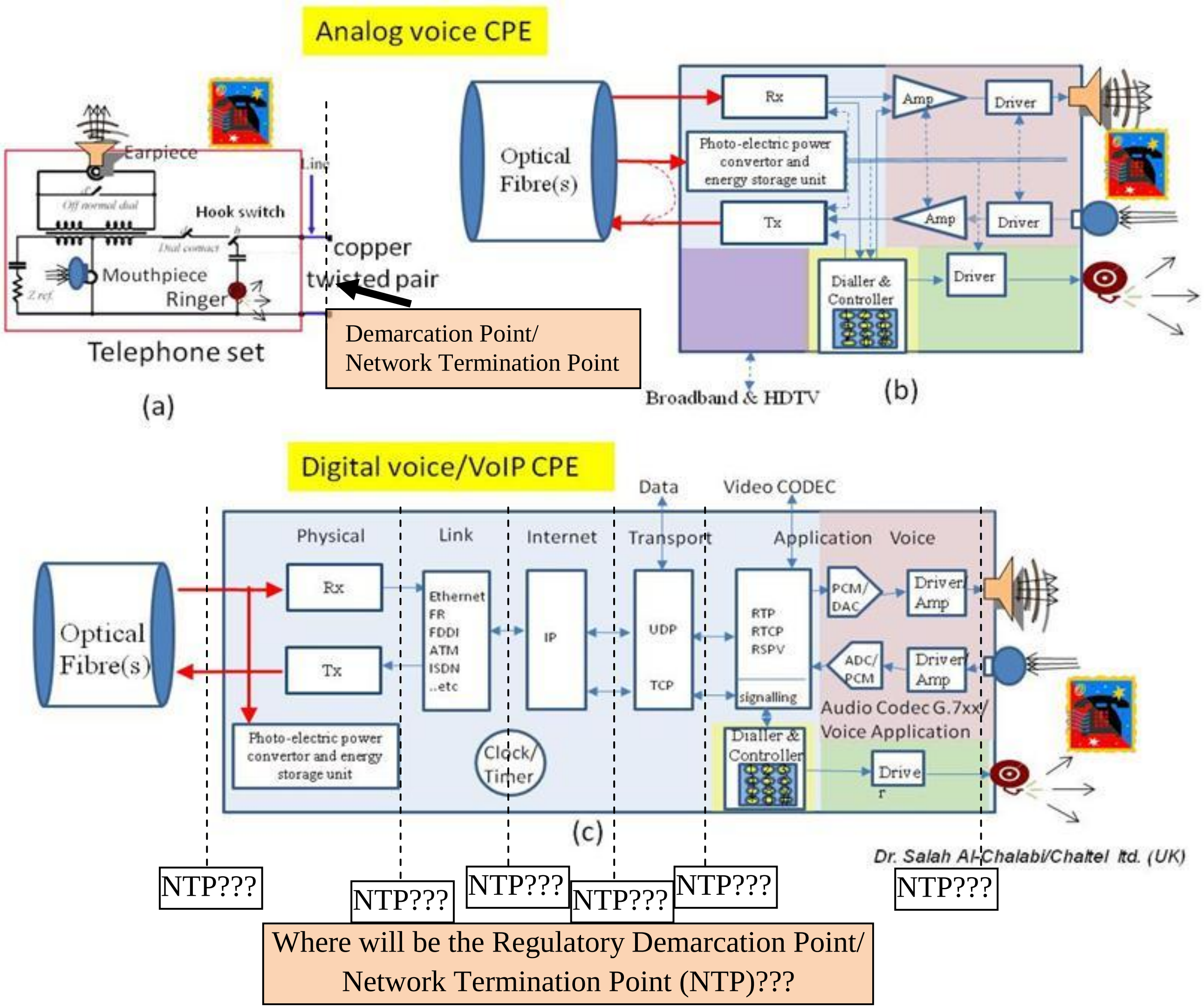

Figure 5: Essential components of telephone CPE (a) copper-based analog telephone with centralized powering (b) fiber-based analog telephone with centralized optical powering (c) fiber-based digital VoIP telephone with centralized optical powering

Sub-system / State	Tx	Amp. Tx	Driv. Tx	Rx	Amp. Rx	Driv. Rx	Driv. Ringer	Control.	Clock	Link Ethernet	IP	UDP/ TCP	RTP RTPCP RPSVP	CODEC	Total (mW)
Outgoing															
(ON hook) Q															
(OFF hook) O															
(OFF hook) D															
(OFF hook) I															
(OFF hook) D															
(OFF hook) R_o															
(OFF hook) C															
(ON hook) Q															
Incoming															
(ON hook) Q															
(ON hook) R															
(OFF hook) C															
(ON hook) Q															

Power Consumption of Each System Component of an Analog Telephone in the Different Standard Telephone States for Outgoing and Incoming Calls:

Q: Quiescent/Idle state (ON-hook)
O: OFF-hook state (Loop)
D: Dialling state (OFF-hook)
I: Inter-digital dialling state (OFF-hook)
C: Communication state (OFF-hook)
R: Ringing state (ON- hook)

Power Consumption of Additional System Components of a Digital VoIP Telephone in the Different Standard Telephone States

Table 2: Power Consumption Spreadsheet of the Analog Telephone and Digital VoIP Telephone in the Standard Telephone States

Access Network/ CPE		Quiescent, Call & Ringing Average Power Consumption (mW)			Quiescent, Call & Ringing States Durations (hr)			CPE Average Consumed Electrical Power per Day every Day (mW) I_p	Powering Architecture
		Quiescent State I_q	Call (Loop) State I_c	Ringing State I_r	Quiescent Duration T_q	Call Duration T_c	Ringing Duration T_r		
Copper twisted pair*	Copper POTS standard telephone	1*	300*	1,000	23.5	0.4	0.1	10	Centralized (over copper)
Copper twisted pair	ADSL2 Modem + standard telephone (all-IP)	2,400	2,700	4,300	23.5	0.4	0.1	2,408	Local
Copper twisted pair or Cat 5	VoIP ATA + standard telephone (all-IP)	1,300	2,400	3,500	23.5	0.4	0.1	1,328	Local
Coaxial	DOCSIS 3.0 + standard telephone (all-IP)	6,200	7,200	8,100	23.5	0.4	0.1	6,225	Local
FTTN/C	VDSL2 + standard telephone (all-IP)	4,700	5,600	6,300	23.5	0.4	0.1	4,722	Cluster
	G.fast + standard telephone (all-IP)	????	????	????	23.5	0.4	0.1	????	Reverse or Cluster
Optical Fiber (FTTH)	GPON ONT + standard telephone (all-IP)	3,500	5,300	6,000	23.5	0.4	0.1	3,540	Local
Optical Fiber (FTTH)	Proprietary ONT (non-standard) + standard telephone	1	30	600	23.5	0.4	0.1	4	Centralized (optical power over fiber)
Optical Fiber (FTTH)	Proprietary ONT (non-standard) + standard telephone	1	30	600	15.7	8	0.3	18	Centralized (optical power over fiber)
*** Specified in CFR 47 – Part 68 and TIA standard 968 in USA, ETSI standards in the European Union (EU), and ITU internationally**									

Table 3: Comparison of Power Consumption per Day of Different Wireline CPEs