Response to Ofcom Strategic Review of Digital Communications

Dr. Salah Al-Chalabi (Chaltel Ltd. – UK); Filed 2 October 2015

Background:

On 16 July, 2015, Ofcom published a consultation document titled "Strategic Review of Digital Communications". The aim of the review is to make sure digital communications markets continue to work for consumers, citizens and businesses. It considers future policy challenges across fixed, mobile and content sectors, including:

- investment and innovation, delivering widespread availability of services;
- sustainable competition, delivering choice, quality and affordable prices;
- empowered consumers, able to take advantage of competitive markets; and
- targeted regulation where necessary, deregulation elsewhere.

The consultation document also states Ofcom's duties set out in the Communications Act 2003 to further:

- the interests of citizens in relation to communications matters; and
- the interests of consumers in relevant markets, where appropriate by promoting competition.

The document states that in addition to this principal duty, Ofcom's duties include, amongst many others, ensuring that the UK has a wide range of electronic communications services, including high-speed services such as broadband. In particular, Ofcom must have regard to the:

- desirability of encouraging investment and innovation in relevant markets; and
- the desirability of encouraging the availability and use of high speed data transfer services throughout the United Kingdom. "

This is a response to Ofcom's consultation covering mainly the related topics of "Widespread availability of services" (Question 3) and "Network evolution and the availability of 'legacy' services" (Question:23). It offers a general framework for analysing the impact of technology and network transitions and evolution on telecom services, including current universal services, supported by the public electronic communication networks and electronic communication services regulated by Ofcom in the UK. The framework is used to analyse the impact on telephone service availability and its powering to ensure uninterrupted access to emergency service due to technology transition in the access network from copper to optical fibre, or wireless access network. The framework can also be used to analyse the impact of the transition in the network layer from circuits switched Time-Division-Multiplexing (TDM) to Internet Protocol (IP) packet switched network.

A Framework for Analysing the Impact of Technology Transitions on Regulated and Non-Regulated Telecom Services in the UK:

The guiding principles of the framework for assessing the impact of technology transitions on the services supported by public networks regulated by Ofcom are: Investment for widespread service availability, Competition, Customer empowerment, and targeted regulations. In contrast, the FCC (USA Regulator) started in 2013 consultations on Technology Transition, where the main "technology neutral" policy guiding principles are: Public safety, Universal access, Competition, and Consumer protection. The FCC's Chief

Technology Officer offered a three-layer technical architectural model consisting of Application, Transport and Network, and Physical layers identifying the different layers where technology transitions are taking place. This architectural model together the guiding principles form the framework for the Review to analyse the impact of technology transitions. Dr. Salah Al-Chalabi (Chaltel Ltd. – UK) filed a contribution[1] , please find attached, to the FCC consultation expanding the framework, where the guiding principles are mapped onto the regulated services (application layer) offered by the public switched network (network layer) over the physical layer (wireline and wireless) shown in figure 1. The paper uses the framework to analyse the impact of some technology transitions in the access network on the services delivered to consumers over the public network. The particular technology transitions analysed are: from wireline to wireless physical layer (copper retirement), transition in the Customer Premises Equipment (CPE) from analogue voice service to CPE with Transport and Network IP layer supporting digital voice (VoIP) service, transition in the telephone exchange equipment from digital TDM voice switching to VoIP routing, and finally the technology transition in the access network from copper twisted-pair to optical fibre in the physical layer (copper retirement).

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…etc. However, in the case of a non-functioning market, where competitive market forces fail to deliver the services to the citizen, 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 analogue 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 achieved. 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 will increase with increased service bandwidth and CPE functionality. Of course, each transmission medium in the physical layer can only support services suitable for that medium. For instance, mobile services can only be offered over wireless transmission, while wireline (guiding medium) can only support services at a fixed location. However, very high bandwidth services are best supported over guiding medium; such as optical fibre (more than 30,000 GHz bandwidth), so a transition from wireline only to wireless only will offer mobile services, but will not support future high bandwidth applications and services due to the limited wireless spectrum/bandwidth. Of course, wireless and wireline connections can complement each other to offer very high bandwidth and high service availability over wireline connection, and mobile services over wireless connections.

In general, a transition in one layer might require transition in another layer. For example, services requiring more than 30 Mbps/customer over distances of 3 km can only occur if the physical layer supports this transmission rate per customer over such distances. For example, an all-copper twisted-pair infrastructure can provide maximum capacity of 20 Mbps up to 1 km using ADSL technology, so a transition from an all-copper access to a network containing fibre network (FTTH, FTTN/C, HFC) over 1 km must occur to deliver the 30 Mbps service.

[1] A Framework for Analyzing the Impact of Technology Transitions on USA Regulated Telecom Services - Particularly Transition from Copper to Fiber; Notes to the FCC Technology Transition Task force (Jan. 15, 2014)-GN Doc13-5, 12-353, 11-60

The above examples illustrate the usefulness of the model as a framework to identify and assess the impact of technology transitions on services currently regulated by Ofcom. To elaborate on the model usefulness, Figure 2 shows technologies and architecture of a national telecom network to deliver communication services to end users over different electronic communication networks. Figure 2 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 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. Clearly, the two regulatory interconnections/interfaces that can be impacted by technology transitions are: the customer-carrier interconnection and the carrier-carrier interconnection. A technology transition in the carrier-carrier connection can occur; for instance from TDM or Circuit Switching to IP routing, while the customer-carrier connection will be impacted by a transition of from copper to optical fibre. The latter technology transition will impact the regulatory interface, over which power is delivered to the CPE, "Network Termination Point", which determines the architectural interface and sets the functionalities of the interface and the responsibilities of the Public Network Provider/Operator and the customer.

Q3: We are interested in stakeholders' views on the likely future challenges for fixed and mobile service availability. Can a 'good' level of availability for particular services be defined? What options are there for policy makers to do more to extend availability to areas that may otherwise not be commercially viable or take longer to cover?

The above framework can obviously contribute to current debates on the "broadband service definition and availability" which is obviously highly dependent on the availability and capability of deployed network technology supplying the bandwidth required by the service. The definition should be related to the services offered, including quality of service, which in turn depends on the network technology used as shown in figure 1. Of course, arbitrary quantification of ambiguous terms, such as "broadband, super-broadband, ultrahigh-broadband, super-ultrahigh-broadband, extremely-high-broadband…etc" are widely used in the public media and marketing literature to mean any "up-to" convenient bandwidth (120 kbps 1Mbps, 10 Mbps, 30 Mbps, 100 Mbps, 200 Mbps, 400 Mbps, 1 Gbps, 10 Gbps, 40 Gbps…etc) to define the service in the upstream and downstream to serve as particular "debating point".

Clearly, the definition of the "service" should depend on the service characteristics itself, which in turn will determine the required network technology to deliver the service and the investment made in the technology, rather than "debating point" that is used to support an argument by a particular stakeholder.

Optical communication systems can compete with traditional twisted-pair copper systems in delivering universal telephony. However, they must achieve the same levels of cost and availability, and must satisfy the same regulatory requirements. An innovative optical communications system that can meet these requirements can be designed 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, which covers urban and rural areas in the UK. Delivering voice over fibre as a Universal Service at comparable cost with that of delivering it over copper removes the uncertainty in service take-up over fibre, and eliminates the investment risk in a FTTH infrastructure. Superfast, Ultrafast, and beyond, broadband data and HDTV services can be added to this future-proof infrastructure, when requested by the customer, with much lower incremental cost than would be needed for copper-based systems. The proposed optical communication system consumes power comparable to telephone system over copper twisted pair connections.

The lowest cost upgrade strategy is to install the “lifeline” voice system as a 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 can then be exploited to deliver the very high bandwidth advanced services, which twisted pairs and coaxial cables can not deliver over distances of 10 km.

This transition from copper to optical fibre in the physical layer with centralized optical powering can support Universal Service telephony and offer high service availability and high network reliability and rapidly restorable critical communication infrastructure impacting positively on Public Safety and Homeland Security. The very high bandwidth of optical fibre (more than 30,000 GHz) connection provides the future-proof broadband network required to connect customers in urban and rural areas, and encourages competition and innovation.

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

Currently standardised FTTH technology can deliver this service, but fails to deliver regulated services, such PATS requiring uninterrupted access to emergency services, consume high power, and require costly installation.

In comparison, FTTC or FTTdp using copper twisted-pair can deliver 1 Gbps service, using G.fast technology, over a distance of less than 100 m from the customer premise. In addition, the reverse powering architecture proposed to power the electronic in the distribution point from customer premises is much less reliable, and more costly to customers than centralised powering.

Transition from Copper to Optical Fibre Access Connection and Optically Powering Customer Premises Equipment over Optical Fibre to Maintain Uninterrupted Access to Emergency Service over the “Lifeline”

Several network operators are considering, or implementing the transition from Circuit-Switched/TDM PSTN network to all-IP switched network to reduce cost, and a transition from copper based access network to an optical fibre network, offering high bandwidth services, or a transition from wireline to wireless access network of lower cost. These transitions raise a number of challenges. One of those challenges is that next generation voice networks may not be as resilient as the PSTN. Legacy PSTN networks offer very high levels of resilience (99.999% five nines) to consumers, particularly in the event of a power failure to the home because it relies on centralised powering from the local exchange which has a primary battery, secondary back-up battery, a diesel generator with fuel, and trained staff to maintain and restore service in case of commercial power outage. This has been particularly important given the historic role of the PSTN providing access to emergency services.

Ofcom and the FCC in the USA recognised the importance of CPE power backup for continuous operation of the telephone service, and in 2014 the FCC initiated a Rule Making procedure which led to an Order in August 2015. Dr Salah Al-Chalabi contributed[2], please find attached, to the FCC's consultation. 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", addressed mainly the technical and system architecture aspects related to CPE powering and back-up power to provide uninterrupted access to emergency services , whose importance to public safety and homeland security has been clearly recognized by the FCC.

Dr. Al-Chalabi first presented a general national network architecture and the access network architecture, figure 2 and 3, to identify the regulatory interconnections impacted by technical transitions and the relevant regulations together with the standardised network equipment powering architecture in Table 1. A methodology is then offered that can be used to compare the power consumption of different CPEs with different functionalities and bandwidths, Table 2 and 3, and set the target for CPE consumption that can be optically powered over optical fibre employing centralised optical powering architecture to provide uninterrupted access to emergency services in case of power outage for long durations. The contribution also offers 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 telephone during lengthy commercial power failures.

The steps of a general methodology developed by Dr. Al-Chalabi 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)
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

[2] 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, Dr. Salah Al-Chalabi (Chaltel Ltd. –UK) –(Nov. 28, 2014); Filed in Dockets: PS 14-174, GN 13-5, WC 05-25, RM-10593, RM-11358

Dr. Salah Al-Chalabi would be happy to present to Ofcom the detailed results of his study on the transition, figure 4 and Table 3, of the CPE from: analogue voice telephony to digital voice over IP (VoIP) in the application, transport and network layers and its on impact 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. Table 2 compares the different architectures for powering the access network. 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 analogue 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 analogue 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.

Another transition is from wireline to a wireless connection in the physical layer, which will change the telephone powering architecture from centralized powering to local powering with battery backup in case of power outage at CP. This transition will result in lower service availability and lower network reliability and slower restorable critical communication infrastructure impacting negatively Public Safety and Homeland Security. Of course, having both wireline and wireless connections will provide two independent connections to the public network which improves Public Safety.

The final technology transition considered is from a copper twisted-pair to an optical Fibre-to-the-Home (FTTH) physical layer. The driver for this transition might be offering multi-services of new very high bandwidth applications in addition to telephony, exploiting the future-proof optical fibre infrastructure of more than 30,000 GHz bandwidth, at low cost over distances of more than 10 km. However, the currently standardized FTTH GPON and EPON technologies can deliver gigabit services, but rely on battery backup at customer premises to maintain the "lifeline" telephone service in case of power failure. This is an expensive solution that offers lower availability than the 99.999% (five nines) which copper based networks delivers.

To solve this problem, centralized optical powering over optical fibre can be used 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. The very high bandwidth of optical fibre (more than 30,000 GHz) connection provides the future-proof broadband network required to connect customers in urban and rural areas, and encourages competition and innovation. In addition, such low power consumption optical communication systems offer not only low-cost universal services, but also future-proof optical broadband and environmentally-friendly local communication network supporting the efforts of the FCC and USA government to reduce the power consumption and carbon footprint of the communications sector.

Currently standardised FTTH technology can deliver this service, but fails to deliver regulated services, such PATS requiring uninterrupted access to emergency services, consume high power, and require costly installation.

In comparison, FTTC or FTTdp using copper twisted-pair can deliver 1 Gbps service, using G.fast technology, over a distance of less than 100 m from the customer premise, and the connection from the street cabinet or distribution point to the local exchange must be fibre. In addition, the reverse powering architecture proposed to power the electronic in the distribution point from customer premises is much less reliable, and more costly to customers than centralised powering.

The FCC Order was published in August 2015 requiring a local backup power to non-line-powered telephone service to operate the CPE for 8 hours duration (not specifying the telephone state) which should be increased to 24 hours in three years.

In contrast, Ofcom have previously consulted twice on CPE power backup, the first in 2007 requiring a battery of 4 hour backup duration, and the second consultation in 2011 reducing the 4 hour backup to 1 hour battery backup to allow emergency calls in the event of a power failure. This implies that Ofcom consider the property and safety of the British citizen can be protected with 1 hour backup, while the FCC considers the property and safety of the America citizen requires more than 24 hours of backup power.

Ofcom's Review states "Going forward, we are open to alternative approaches, but our guiding principle remains that reliable access to the emergency services is of fundamental importance, and that the deployment of new voice networks should not make citizens less safe."

Q23: Where might future network evolutions, including network retirement, offer opportunities for deregulation whilst still supporting good consumer outcomes?
The three-layer architectural model, offered in this response, consisting of Application, Transport and Network, and Physical layers is adequate to identify the different layers where technology transitions are taking place, and assess the impact of technology transitions on Ofcom's consultation guiding principles. This model can be used to analyse the impact of some technology transitions in the access network on the services delivered to consumers over the public network. The particular technology transitions analysed are: from wireline to wireless physical layer, transition in the Customer Premises Equipment (CPE) from analogue voice service to CPE with Transport and Network IP layer supporting digital voice (VoIP) service, transition in the telephone exchange equipment from digital TDM voice switching to VoIP routing, and the technology transition from copper twisted-pair to optical fibre in the physical layer. Dr. Salah Al-Chalabi would be happy to present to Ofcom the detailed results of his study on the transition of the CPE from: analogue voice telephony to digital voice over IP (VoIP) in the application, transport and network layers and its impact 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. Table 2 compares the different architectures for powering the access network, showing that the most resilient and lowest cost architecture is centralised powering. 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 analogue 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 analogue 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. Another transition is from wireline to a wireless connection in the physical layer, which will change the telephone powering architecture from centralized powering to local powering with

battery backup in case of power outage at CP. This transition will result in lower service availability, lower network reliability, and slower restorable critical communication infrastructure impacting negatively Public Safety and Homeland Security. Of course, having both wireline and wireless connections will provide two independent connections to the public network which improves Public Safety.

The final technology transition considered is from a copper twisted-pair to an optical Fibre-to-the-Home (FTTH) physical layer. The driver for this transition might be offering multi-services of new very high bandwidth applications in addition to telephony, exploiting the future-proof optical fibre infrastructure of more than 30,000 GHz bandwidth, at low cost over distances of more than 10 km. However, the currently standardized FTTH GPON and EPON technologies can deliver gigabit services, but rely on battery backup at customer premises to maintain the "lifeline" telephone service in case of power failure. This is an expensive solution that offers lower availability than the 99.999% (five nines) which copper based networks delivers.

To solve this problem, centralized optical powering over optical fibre can be used 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. The very high bandwidth of optical fibre (more than 30,000 GHz) connection provides the future-proof broadband network required to connect customers in urban and rural areas, and encourages competition and innovation. In addition, such low power consumption optical communication systems offer not only low-cost universal services, but also future-proof optical broadband and environmentally-friendly local communication network supporting the efforts of the Ofcom, UK government and EU to reduce the power consumption and carbon footprint of the communications sector.

Currently standardised FTTH technology can deliver this service, but fails to deliver regulated services, such PATS requiring uninterrupted access to emergency services, consume high power, and require costly installation of terminal equipment with battery backup.

The transition from copper to optical fibre 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 fibre connection provides the future-proof broadband network required by the UK government and the EU to connect customers in urban and rural areas, and encourages competition and innovation.

Delivering voice over fibre as a Universal Service at comparable cost with that of delivering it over copper removes the uncertainty in service take-up over fibre, 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 fibre 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 UK government and EU to reduce the power consumption and carbon footprint of the communications sector.

In comparison, FTTC or FTTdp using copper twisted-pair can deliver 1 Gbps service, using G.fast technology, over a distance of less than 500 m from the customer premise, and the connection from the street cabinet or distribution point to the local exchange must be fibre. Making FTTH more suitable than FTTC or FTTdp especially for connecting customers in rural and remote areas. In addition, the reverse powering architecture proposed to power the electronic in the distribution point from customer premises is much less reliable, and more costly to customers than centralised powering.

I hope that this contribution assists Ofcom in analyzing the impact of any technology transition, in particular the power consumption of any CPE, and provides guidance to improving designs, standards, and input to any relevant new Ofcom rules. One such area might be regulatory rules and technical standards for the "Network Termination 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 fibre 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 ETSI standards. 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, imperative that Ofcom 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 Ofcom more detailed information about possible low power optical technology which should provide uninterrupted access to emergency service over fibre 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 UK and European Union.

The FCC published in August 2015 an Order requiring a local backup power to non-line-powered telephone service to operate the CPE for 8 hours duration which should be increased to 24 hours in three years.

In contrast, Ofcom have previously consulted twice on CPE power backup, the first in 2007 requiring a battery of 4 hour backup duration, and the second consultation in 2011 reducing the 4 hour backup to 1 hour battery backup to allow emergency calls in the event of a power failure. This implies that Ofcom consider the property and safety of the British citizen can be protected with 1 hour backup, while the FCC considers the property and safety of the America citizen requires more than 24 hours of backup power.

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

Dr. Salah Al-Chalabi

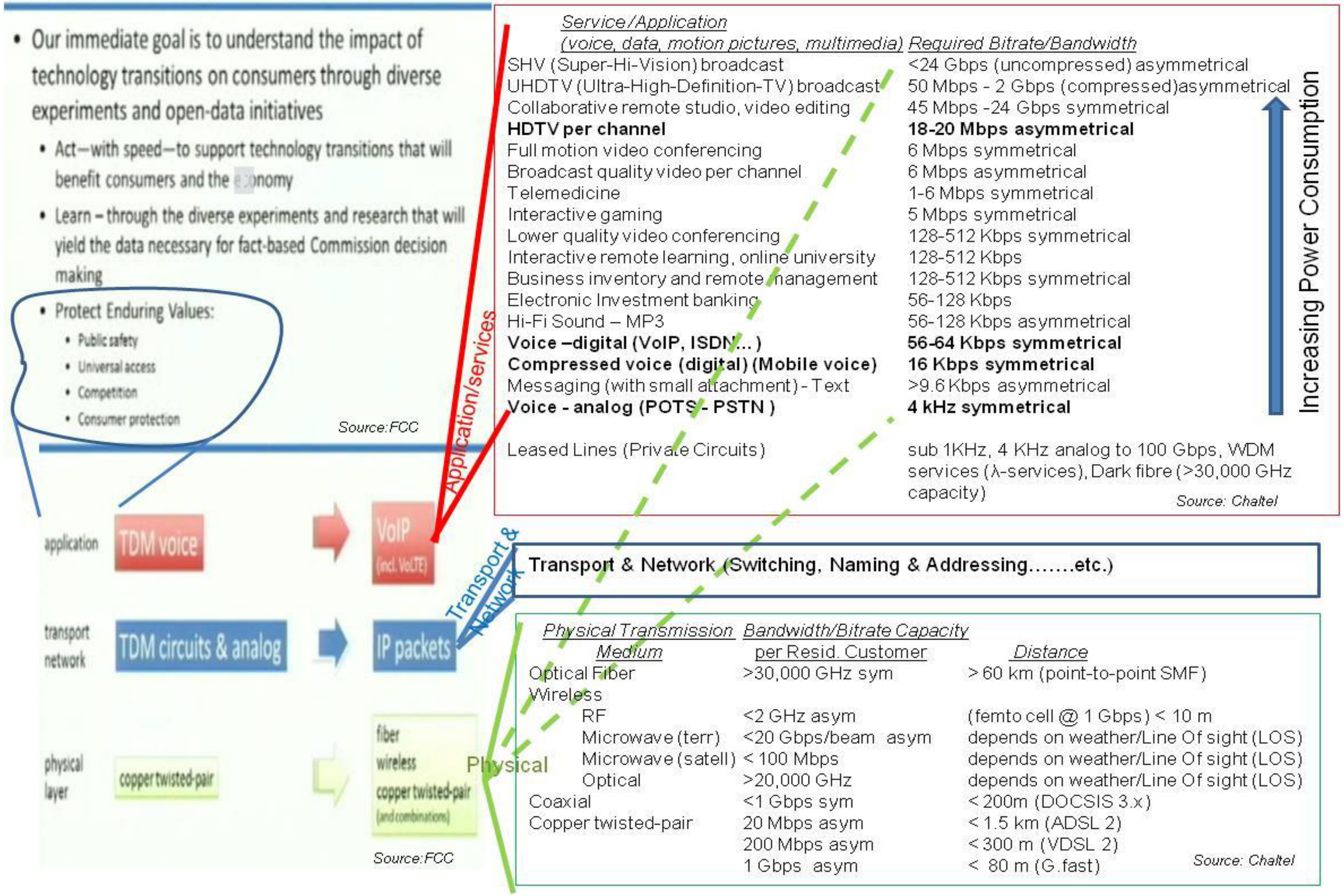

Figure 1: Framework for Mapping the Impact of Different Technology Transitions in the Different Architectural Layers onto Telecommunication Services/Applications and the Ofcom’s Duties and Review Aims

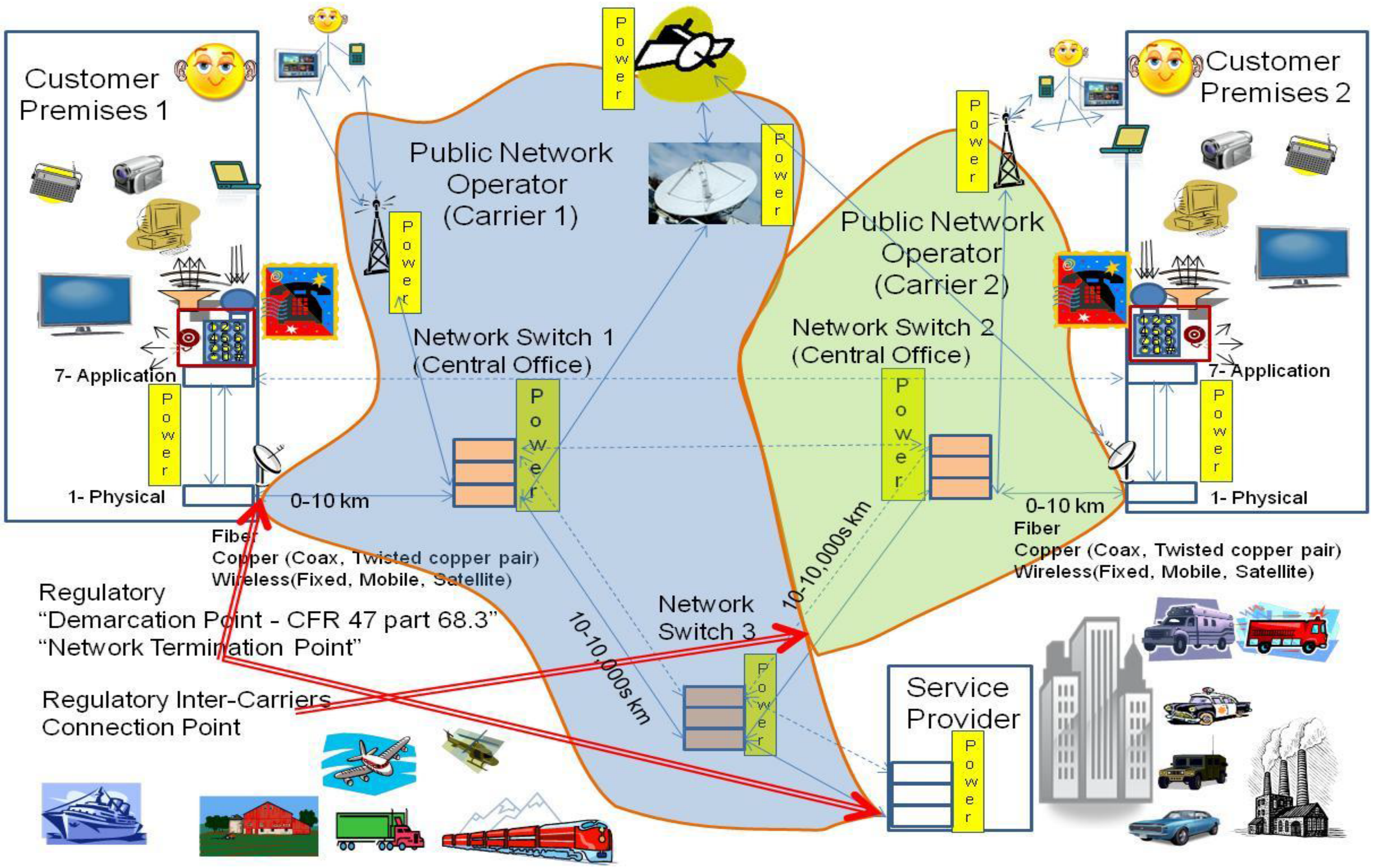

Figure 2: National and Global Telecommunication Network and Systems Architecture

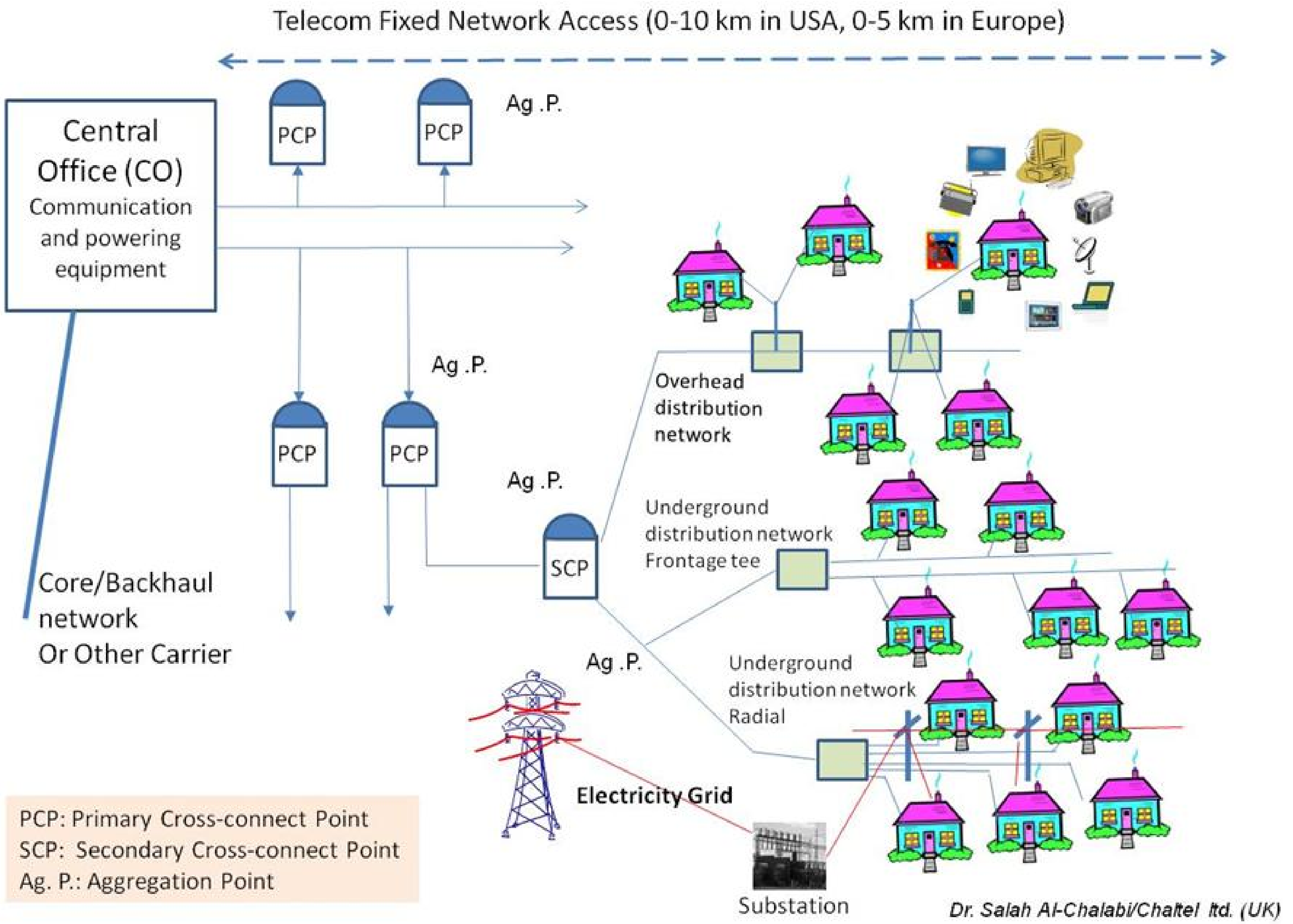

Figure 3: Telecom Public Fixed Access Network and Local Electricity Grid

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

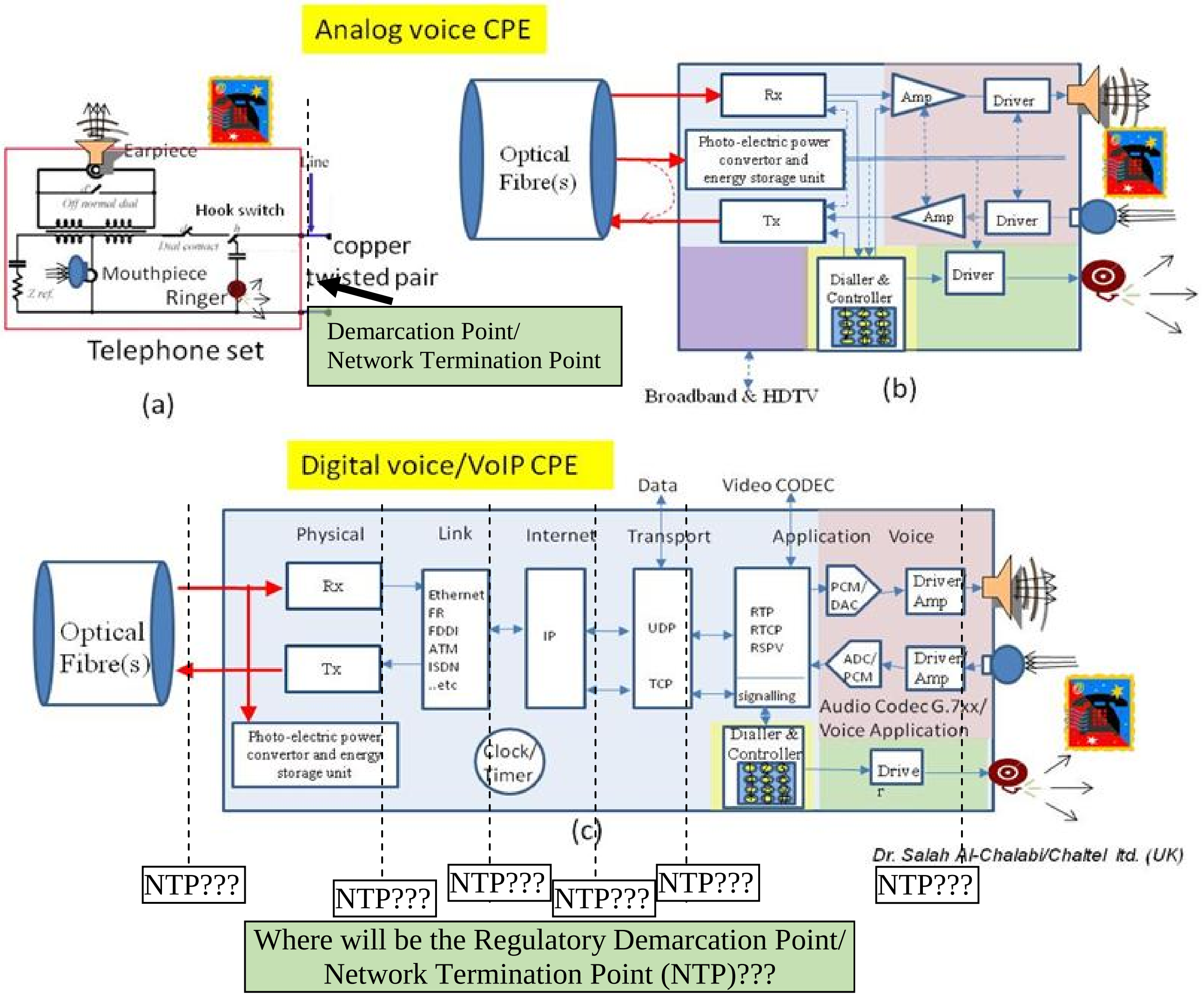

Figure 4: Essential components of telephone CPE (a) copper-based analog telephone with centralized powering (b) fiber-based analog telephone with centralized optical powering (c) fiber-based digital VoIP telephone with centralized optical powering

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															

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