Networked Media Position Paper

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This document has been drafted by a set of NEM members and Networld2020 members (see list of contributors below) under the leadership of Pierre-Yves DANET (Orange, NEM Vice Chairman), and being approved by the NEM Networld2020 Steering Board

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Executive Summary

The NEM Initiative is one of the recognized European Technology Platform s (ETPs) of Horizon 2020. The NEM ETP aims at building sustainable European leadership in content, media, and the creative industries. With the launch of the Horizon 2020 programme, the renewed NEM platform is pursuing its objective to promote an innovative European approach to convergent Media, Content and Creativity towards a Future Media Internet that will enhance the lives of European citizens through a richer media experience.

NetWorld2020 is the European Technology Platform for communications networks and services. Communications networks enable interaction between users of various types of equipment, either mobile or fixed. They are the foundation of the Internet. The NetWorld2020 European Technology Platform gathers players of the communications networks sector: industry leaders, innovative SMEs, and leading academic institutions.

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I- Foreword

Networld2020 and NEM ETPs have decided to work together in order to align their strategic agenda. NEM ETP covers the entire content sector which needs networks to be delivered to end users (broadcast, unicast, multicast), Networld2020 ETP covers all the future internet sector (wired, wireless and satellite) which needs content to be filled, so there is a need to understand each other's in order to setup consistent agendas.

Such a working group should have the objective to push requirements from content & media domain in order to influence the design of the future Network infrastructures and service research (usage push) but also should have to share network and service innovation (techno push) that could offer new possibilities to content providers and creative industries. Such a working group should also have to address the Networked Media value chain and corresponding business models

This position paper is the first concrete result of the working group, it describes the research topics that need to be address in order to insure consistency between Content and Media requirements and future network capabilities.

II- Content distribution

The digital revolution is affecting also the area of content distribution, with a series of challenges and opportunities as well as many current and potential technological developments and transformations in business models.
From a technological point of view, a large part of the future developments will hinge on the evolution of networks. In fact, for the first time ever, we have the technologies in hand to transform the way networks are built and services are delivered, to create a global, high performance, scalable, intelligent, integrated IP-IT network.
There are essentially 5 coupled dimensions that need to be addressed to enable this true digital revolution:

- First, there is the end user 'device factor', wherein we need to enable 10x as many devices, but with economics that will be up to 10x lower per device.
- Second, there is the end user 'demand factor', which will require 100x more bytes delivered, which at today's economics means 100x lower cost per byte.
- Third, there is the network 'scalability factor', which requires a unification of tens of different network domains and the unification of hundreds of disparate operator networks into a federated global and open network.
- Fourth, there is the 'elasticity factor', which requires that the dedicated systems that were used to reliably deliver a fixed set of services be replaced by IT systems that deliver an infinite set of services with a completely different reliability model.
- Fifth, there is the 'velocity factor', which mandates a 100x increase in the rate of service onboarding, and an attendant 100x decrease in service management complexity.

Spanning across all these challenges are the great 'transversal' challenges of massively improved energy consumption and massively scalable security, which are also essential to solve. Future technological developments will work towards addressing this 100x device-demand-scalability-elasticity-velocity-energy-security issue.

Looking at what has happened in computing devices, it is remarkable to observe how fast tablets have become the most popular computing devices, displacing desktops and then laptops in record time. This may well be the key to the future of content distribution. Tablets are inherently wireless devices, and as such require high capacity wireless connectivity, and also continuous, 'ubiquitous' access to the Cloud because they have limited processing and storage power due their size, weight and cost constraints.[1] And last, tablets are both consumer and now increasingly enterprise devices (see the BYOD phenomenon). So, tablets almost single-handedly drive the need for UBB wireless networks, to connect to the Cloud, anywhere, anytime, at home, at work, or anywhere in between. This resonates with a clear trend towards content in motion, everywhere.

Looking beyond tablets, we see that there are many other such future features with similar exponential scaling apparent or predicted, that will also dictate the path to the future: wearable devices and M2M in general show exponential growth, as do Cloud servers and the networking of those servers and VMs using SDN. And if we look at the growth in Wifi Apps as a proxy for the need for UBB wireless access, this connects the two. In short, the future is about tablets and machines connecting to the Cloud over UBB wireless networks, and it is starting now. But the challenge is to achieve this with 10-100x change in the scale and at sustainable economics.

This will have to be looked at within the broader picture of the development of CCIs, ICT and content production and consumption models, making the necessary connections between content, services and networks. CCI SMEs will have to be involved in technology development and uptake and links among them will have to be strengthened. The scale and diversity of EU CCIs shall be leveraged by clusters and clusters of clusters (rather than one Silicon Valley, many interconnected communities).

[1] We are assuming that efforts will tend towards potentiating the networks and Cloud infrastructure more than towards the expansion of the capabilities of devices, even though this will happen too.

A key feature of future scenarios – that is already visible now – will be convergence, particularly in the domain of distribution. Convergence will involve internet, phone, TV, mobile and content (in music, video, gaming, etc.); it will rely on very high speed networks and will be inextricably linked to seamless access to content: the idea of ATAWAD (anytime, anywhere, on any device – including 'heavy' content, transmedia). Service quality will need to be adequate to user needs and network and device capabilities; new platforms and services will emerge to deliver content across a range of devices and environments. The underlying motive will be 'smart content on smart devices'.

Technology will have to further drive this convergence: content will be delivered on future 5G networks (including home networks), simultaneously, to a range of devices from whole wall UHDTV displays to mobile handheld devices. Furthermore, it will be a world of IP interconnected devices, the age of the Internet of Things, which will span a spectrum of use cases. Everything from TV and telephony to home lightning can be integrated into one product. Similar to this is the hybridisation of two or more technologies or media, such as Internet TV, portable video, or mobile messaging, which expands the possibilities to modify and extend media in new ways. Also pure media convergence will continue in many fields; for example, book publishing will be more and more interlinked with audio-visual, gaming, etc. Developments in wiring and materials carrying digital information and in the cost and availability of bandwidth will be essential.

III- Content networking

Partner Service Provider and XaaS Asset Provider (NGMN vision document 2015)
Partner service provider and XaaS asset provider models refer to the 5G high-level requirement to allow creation of different levels of relationship between operators and application/service providers. Exploiting flexibility, 5G should be able to support different levels of abstraction and business models as known today (e.g., Infrastructure as a Service, Platform as a Service, Network as a Service) as well as allowing creation of completely new business models not foreseen at the time of writing this document. The key requirement is that Service providers should be able to configure and manage the service, while operators will have freedom to manage and evolve the network.

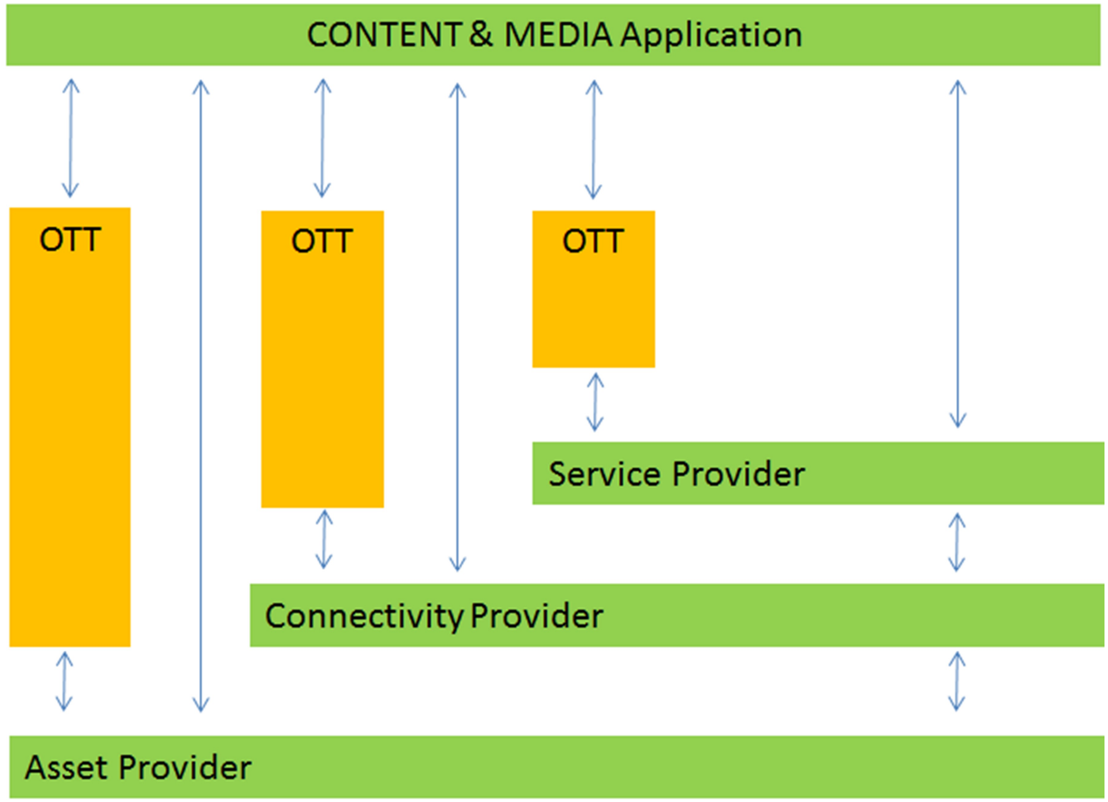
In this context, 5G should provide an abstraction layer as an interface, where all types of in-networking functionality (control plane and data plane related) can be exposed to the application layer functions and/or service providers based on a service level agreement. Application/Service provider will then be able to use sub-set of the network capabilities in a flexible, configurable and programmable manner, and to use network resources depending on their service preference.

These exposed in-networking capabilities or information may include charging capabilities, authentication, mobility, reliability functions, mobile user's footprints, etc. For example, a 3rd party application can be charged for its user's traffic instead of charging to its users; operators can provide (regularly or on-demand) to an intelligent traffic management application the number of UEs presence in a certain area without violating user's privacy. Some radio information can also be exposed, such as real-time loading, QoS, UE measurement report, mobility, signal strength, etc. Real-time QoS may for example allow video applications to adjust UL/DL video bit rates to improve streaming experience.

Role	Business Models	
Asset Provider	**XaaS: IaaS, NaaS, PaaS** Ability to offer to and operate for a 3rd party provider different network infrastructure capabilities (Infrastructure, Platform, Network) as a Service.	**Network Sharing** Ability to share Network infrastructure between two or more Operators based on static or dynamic policies (e.g. congestion/excess capacity policies)
Connectivity Provider	**Basic Connectivity** Best effort IP connectivity in retail (consumer/business) & wholesale/MVNO	**Enhanced Connectivity** IP connectivity with differentiated feature set (QoS, zero rating, latency, etc..) and enhanced configurability of the different connectivity characteristics.
Partner Service Provider	**Operator Offer Enriched by Partner** Operator offering to its end customers, based on operator capabilities (connectivity, context, identity etc.) enriched by partner capabilities (content, application, etc..)	**Partner Offer Enriched by Operator** Partner offer to its end customers enriched by operator network and other value creation capabilities (connectivity, context, identity etc.)

Figure 2: 5G business models - Examples

With 5G, services delivered by operators will go beyond traditional connectivity services. Indeed, 5G Infrastructures will encompass distributed compute and storage resources beyond networking equipment and these resources will be made available on demand towards third parties providing next generation IaaS offers. In addition, thanks to virtualization and apis operators will be able to expose services enablers like authentication, encryption, content delivery caches...
This is very well summarized in the following table coming from NGMN 5G vision paper.
Content industry could benefit from these new operator services to deploy their own services with a limited investment and faster time plan due to maximum reuse of existing enablers and infrastructure



OTT position could be at different level between the content&media application and the infrastructure operator (asset provider)

- OTT could provide the end to end connectivity, the service and the content
- OTT could provide the service and the content
- OTT could provide only the content

IV- Research topics

A number of research topics related to the content delivery has been identified in the NEM Strategic Research and Innovation Agenda.

1. Be ATAWAD (any device and multiscreen), seamless access to any content
2. Support more and more devices (high end but also low end devices)
3. Support higher quality (4K, 8K, 3D, …)
4. Support better latency (games)
5. Could be configured according to the content requirements
6. Support LTE/DVB convergence
7. Support Personal device synchronisation and auto discovery
8. Include Home networking
9. Support B2B streaming technologies based on consumer equipments
10. Support Quality of experience placement of content in the network, graceful degradation, complexity hiding
11. Support Virtualisation of networks (NFV/SDN, seamless connection via tablets to content)
12. Support Networking and computing technologies enabling "Visualisation as a Service" business models
13. Support Very high speed transmission for media (optical and wireless infrastructure), ubiquitous access to it for producers and consumers, strong networks geographically widespread, ultra-broadband

14. Offer New low power wireless protocols
15. Be interoperable
16. Allow rights management and rights information management
17. Improve accessibility for the disabled
18. Allow for handling big data
19. Convergence ;: Internet, phone, TV, mobile and content (music, video, games, book, …)

From these 19 topics, the group has extracted 4 of them that have a real interest for collaboration:

1. Support better latency / real time (games) : SLA (section 3.1.5) + ...
    - A need to define an interface fitting the content application needs.
    - What the application should do to solve a bad latency ?
2. Could be configured according the content requirements : SLA (section 3.1.5)
    - A need for content application to identify the parameters that have to be passed to the network
3. Support Quality of Experience placement of content in the network, graceful degradation, complexity hiding
4. Allow for handling big data (network for big data) - See with NESSi

From these 4 topics, the Joined Networld2020/NEM working group has identified 9 parameters that have to be shared by content providers and network service providers. For each of them, the group proposes a definition, a technical feasibility and a business value study.

These 9 parameters should fulfil the needs of NEM domains:
- Publishing (books) : Security (DRM), end user context
- Film : Security (DRM), end user context
- Music : Security (DRM), end user context
- Audio/Video : Interactivity, Security, end user context
- Advertising : Location, Business model, Augmented reality, end user context
- Designers : Interactivity, virtual reality
- Cultural heritage : Storage, Security, Durability (never lost)
- Fashion : Augmented reality, virtual reality
- Game : Interactivity, end user context, virtual reality

IV.1 Content delivery

Content Delivery Network (CDN) is a set of techniques and optimizations that aim to provide the best Quality of Experience to users combined with optimal use of end-to-end technologies, and network systems, and taking into account macro and micro traffic characteristics.

The challenge of 5G network is to allow the selection of appropriate
- Transmission mode according to audience: Unicast, multicast, broadcast
- Delivery mode according to service type: On demand/Caching or live streaming
- And/Or Network technology according to geographical distribution of the audience: Cellular, terrestrial broadcast, satellite

IV.1.1 : Definition

The **unified scalable A/V format for storage and delivery** corresponds to the unification of formats and protocols and provides the following characteristics:

- A single data stream generation process, including multimedia content compression and packetization, optimized for IP networks.
- The use of a single stream for unicast/multicast/broadcast transmission, and for any kind of temporal limitation such as real-time, delayed on-demand transmission or long-term storage.
- Scalable quality adapted to the device's screen presentation capabilities, the device's processing capacity or the network's state, showing the best quality for each scenario.

- Low overhead due to the use of a very small amount of metadata in comparison to the audio/video content.

The **continuous user quality of experience monitoring for multimedia** consists in the automatic and continuous evaluation of the perceptual audio/video quality in different stages of the transmission chain by means of algorithms based on models of the human visual/auditory system, obtaining similar results to the Mean Opinion Score (MOS).

The main advantage of the QoE (Quality of experience) monitoring is to allow the operator or content provider to make decisions about compression or network parameters in order to maintain a certain level of QoE.

Traditional content delivery strategies such as multicast technologies (widely deployed in IPTV – Internet Protocol TV) or one-to-one unicast progressive downloads might not be suitable any more in nowadays context and emerging media services. In early 2000s, internet users have seen a greater network bandwidth, especially in the last mile, resulting with the emergence of Over-The-Top (OTT) media services like live High Definition (HD) streaming, which are not one-to-one unicast by nature anymore. Moreover, the end user device eco-system has evolved to a wide variety of different devices and screens which are hardly controlled by the content distributor or producer. In fact it makes it very difficult to keep on using traditional IPTV approaches where the network and the receiver are highly controlled, as the Internet Service Provider (ISP), the infrastructure owner and end user device are owned or managed by a single company usually the ISP. Finally, in addition to the above, high bandwidth demanding media formats are appearing in order to provide better Quality of Experience (QoE); high resolutions like 4K and even 8K are getting into the market; or different formats for stereoscopic 3D and even 360 omnidirectional immersive content are on the way. For all those, high capacity internet links are going to be needed.

The proliferation of internet devices with remarkable computing capacities such smartphones, tablets or embedded devices is driving users to consume media in a wide range of different services and devices, forcing media providers to cope with different types of formats and representations of the content depending on the client device and network link (FTTH, LTE, WiFi, etc.). Nowadays OTT networks and services are mostly based in widely spread Web technologies, as Web based technologies are emerging as a good environment to build multi-platform services and applications. In order to accelerate Internet and provide scalability for mainstream Internet services (media delivery, web apps and HTTP traffic in general) Content Delivery Networks (CDNs) platforms were born. CDNs tend to deploy content closer to the end user and as a consequence reduce network throughput variability and network congestion. These approaches are feasible and well adapted to HTTP based services, however HTTP was not designed for video services. Current HTTP based streaming technologies are rapidly gaining popularity however they suffer from uncertain latencies, lack of multicast support, synchronization in multi-device environments (i.e second screen use cases) and HTTP related efficiency issues (which might be partially addressed by the adoption and evolution of HTTP 2.0).

Even there is still a long path to walk over with the unicast/TCP (mostly HTTP) aspects (i.e. latency reduction or multi-device synchronization), current emerging network technologies are opening a wide range of options for novel forms of broadcast, multicast and unicast hybrid systems. Multicast technologies haven't found their own way in the public Internet services, mostly because of lack of support by ISPs. LTE standards include Multicast for mobile services, but remain uncertain whether operators will provide support for OTT services or not. It will not be until multiple subscribers can view the same content from a single cell that we can really experiment the benefits of eMBMS (evolved Multimedia Broadcast Multicast Service), as provision of broadcasting channels may cause overload on the cells. Customer demand and market context and evolution will play a relevant role here.

Advanced network technologies and approaches like Software Defined Networking (SDN) or Network Function Virtualisation (NFV) provide the appropriate framework to build a logically centralized multicast network controller completely software based. Multicast tree calculation, authentication and any other multicast event could be implemented as a software application over an SDN platform resulting in a simply manageable multicast solution. By the hand of cloud and virtualization technologies SDN and NFV approaches might become a reality in the industry, giving a huge elasticity to ISPs in order to allow and provide new advanced services for such multicast on demand without having to go through prohibitive infrastructure investments, as most of the services could run on Custom off the shelf (COTS) servers. Other network protocols, which can be complementary, are raised for that purpose, like the Automatic Multicast Tunnelling. This protocol is provides unicast tunnels using UDP to deliver content from core networks right out across the last mile until user's premises. It implies a client/server application, so requires specific software in the end device to communicate with a host system.

The use of HTTP delivery provides stop-gap measures for reliable streaming in current heterogeneous networks enabling the usage of a large quantity of COTS servers for large events. It is a scalable solution by scaling and increasing OPEX in cloud platform management. However beyond this option the trend is that operators, vendors, CDN providers and content owners are arriving to the conclusion that a higher cooperation between them is needed to come up with efficient network protocols and services such as multicast or broadcast and which are going to be essential in the future for live OTT services at large scale.

Initiatives such DVB-T2 and LTE-A+ and the recently launched 5G initiative open up the door for real convergence of broadcast and broadband technologies. Adapting LTE technology to traditional high broadcasting DVB towers enables the possibility of fruitful cooperation between cellular and broadcasting networks, reduce network loads, energy consumption. LTE-A+ devices would be capable to receive broadcast signals without having to add specific receivers into the mobile device. It makes it possible to send DVB-T2 TV HDTV channels while embedding some other streams for 4G LTE-A+ smartphones, laptops or tablets.

IV.1.2 : Technical feasibility

Novel application segments and use cases

Content Distribution Networks play a vital role in the efficient distribution of information and media and their importance will only increase as web pages include richer media and continue to grow in size, IP networks become the de facto means of media distribution and as the drive towards high fidelity media pushes bandwidth requirements to new heights. But besides the well established distribution functions, a set of novel application segments will benefit from media storage and processing in the edge, pointing to a new range of functionalities for CDN's.

High Fidelity Media

The driving force of immersion and immediacy will continue to push the audiovisual quality of media content to higher levels, including higher resolutions, dynamic ranges and frame rates. And after a false start, 3D screens can be counted on to make a come-back, both on wall mounted and handheld screens. Even with the next generation of video codecs that can be expected to arrive in the 2020-2025 time frame, bandwidth requirements will continue to rise. Especially 360 panoramic video (cinematic VR) consumed on Virtual Reality headwear generates taxing requirements, up to a tenfold increase in bandwidth demands. In combination with changing media consumption patterns, away from linear broadcast TV and towards on-demand viewing depending on unicast delivery, powerful content distribution networks will be an absolute necessity to tame the bandwidth hog of future media.

Machine Generated Content

User Generated Content (UGC), enabled by smartphone cameras and social media platforms created an avalanche of personal pictures and videos documenting the daily life of millions of people. The emergence of autonomous cameras that enable an automatic world logging will generate a deluge of audiovisual content, several orders of magnitude larger than the UGC wave. Autonomous cameras include cameras installed in home environments for home security and to automatically capture memorable family moments, cameras in public spaces that serve a similar dual purpose (for instance capturing amateur sports matches and musical performances), wearable cameras donned by police officers, customer facing employees and the general public and follow-me drone cameras. These cameras will continuously capture and stream towards the cloud, where advanced analytics will filter out the relevant segments and scenes. Machine Generated Content requires something we could call an inverse CDN, tunnelling a multitude of live media streams to content analysis and transformation platforms. Analysis for activity inference will furthermore make use of additional sensor data like precise location and movement information of people and objects to improve algorithmic performance. Possible media transformations include anonymization of people for privacy reasons and the automated editing of multiple media streams into a coherent story. Content distribution functionality has to evolve to also include content aggregation, depending on powerful analytics and media transformation capabilities.

Ambient Media
A substantial part of linear broadcast television is consumed in the home in an ambient mode, as a type of visual radio in the background, accompanying daily activities like cooking, cleaning, taking care of kids, playing and studying. The arrival of affordable superflat ‘sheet displays’ that can be stuck against the wall in kitchens, bathrooms and bedrooms will create the possibility of a multi-room ambient media experience, mimicking the multi-room music consumption pattern that is already common today for streaming audio. And indeed similar to streaming audio, the ambient media consumption pattern will shift from broadcast TV to personalized contextual playlists. Ambient media will consist of a mix of content requiring low to medium attention levels that are compatible with home activities like sitcoms, music performances, reality and talk shows, combined with audiovisual notifications and messages from social media and weather and news updates. Content distribution will have to take into account contextual information gathered from home and wearable sensors pertaining to location, identity and activity to curate a combination of on-demand and live content elements into a continuous personalized media stream. The user may fine tune the proposed selection via handsfree interaction like voice and gestures, skipping segments or explicitly demanding certain genres and topics. And contextualized activity-aware advertising is of course very attractive service to brands.

Life Coaching
GPS based navigation systems brought great convenience to daily life, rather than studying paper maps in advance of a trip, we can hop directly in our cars and depend on turn-by-turn instructions adapted to real-time traffic conditions. The massive deployments of sensors, embedded in the environment or worn on our bodies, in combination with wearables like always-in earbuds, haptic and glanceable watches and ultimately augmented reality headwear, generate an infrastructure for ‘GPS for Life’ applications. Virtual coaches and artificial experts will provide us with relevant and timely cues to optimize every activity in daily life: cooking a new recipe to perfection, learning new yoga positions and repairing the kitchen sink. Life coaching services depend on the aggregation and analysis of multiple sensor feeds to infer the status of ongoing tasks and the delivery of synchronized assistive hints via a variety of modalities. And because the information delivery should be tuned to the pace of physical activities, the latency of the complete loop from sensor acquisition to assistance play-out should remain below 50 ms. Edge nodes like CDN’s with media storage and processing functionality will play an important role in the realization of life coaching services. The discussed example of life coaching services is however only one application segment in the broader domain of augmented reality which in general requires the timely delivery of information objects, triggered by the user’s physical activity in the real world.

Cooperative work and remote editing
Besides a faithful high-quality audio-visual representation of the participants, an effective tele-conferencing session often requires an efficient shared access to digital artefacts that can be collaboratively inspected and manipulated. The conferencing solution hosts a master copy of whiteboards, slide decks and notes pages in the cloud that can be simultaneously accessed and edited by all communicating parties. With the introduction of 3D capturing equipment, big data analytics and simulation packages, the complexity of the shared digital objects and the associated visualization processes is increasing: dynamic 3D models for manufacturing, medicine and architecture, 360degree and multi-view video, multi-dimensional big data visualization. The data sizes of these complex models and the rendering processing can be challenging for client nodes, especially for mobile devices and for the emerging class of Virtual Reality/Augmented Reality headwear. Hosting the shared digital objects in the cloud, including the personalized point-of-view rendering and manipulation interfaces for the remote participants offers a convenient approach in line with current cloud-based video communication solutions. To limit the network traffic impact of the high-definition video streams of the rendered digital objects and ensure a low latency interaction with them, distributed hosting and processing in edge clouds nearby the conference attendants is a logical next step for content distribution networks.

Research challenges

From the definition given above there are three main areas in which the development and technology evolution in near future will have profound impact on content delivery across various platforms, networks and applications.

1. Evolution of the current unicast technologies compatible with current large networks. Current technologies based on HTTP are still being developed and enhanced and they will still be as they are the current stop-gap solution until there is a real revolution in the network. Multi-device synchronization signalling, latency reduction and control and ABR (Adaptive Bit Rate) are still areas to improve and evolve which might be done at application level. These technologies are the current solution for ATAWAD (Any Time Any Where Any Device).
2. The usage of multicast technologies in OTT unmanaged networks. Enabling unicast/multicast conversions across the networks in a seamless and efficient way come by the hands of introducing SDN and NFV like concepts into the network nodes with COTS equipment. This will be a true enabler for advanced multicast or unicast/multicast hybrid use cases.
3. Convergence of 3GPP and DVB for future TV broadband/broadcasting content. Technologies and concepts like the ones provided in LTE-A+ and DVB-T2 will set the basis for a real convergence within broadcasting networks and cellular broadband networks. They are currently capable to share part of the spectrum. This will be a turnkey technology for highly scalable delivery. This needs to be included in tbe 5G initiatives.

Below, some more detailed topics w.r.t. content delivery are listed.

- Mult-device synchronization and signalling for the current ABR formats.
- Transparent caching in future internet protocols (HTTP 2.0) and is impact in limiting latency.
- Low latency live streaming over HTTP
- SDN and NFV to provide software based multicast services
- Multicast tunnelling over unicast only networks
- Open protocols for streaming over UDP on OTT networks (FEC – Forward Error Correction-, Layered Coding, Multi-path streaming)
- eMBMS in the scope of C-RAN and 5G initiatives
- DVB and 3GPP convergence for mobile devices for very large events and high scalability.

It is to be noted that the MPEG document related to requirements for a future video coding standard is now publicly available at :: http://mpeg.chiariglione.org/standards/exploration/future-video-coding/requirements-a-future-video-coding-standard-v1.

The notion of “participation” or “participatory networks” pertains to scenarios where complex applications or a group of applications explicitly announce their communication needs and patterns to an underlying infrastructure. So far, this has mostly been considered in the context of data-center networking but the extension both beyond the data center and beyond networking towards more general IT/networking scenarios is obvious.

In the context of networked media, this allows content delivery or content distribution platforms, for both static content like video as well as dynamic content like game servers, to negotiate and communicate with the underlying infrastructure. Plausible goals are to improve QoE and efficiency, reduce time to deployment or energy consumption, etc. Overall, the goal is relieve operators and developers of the need to steer their application platforms manually or with a lot of manual interventions and to rather enable such platforms to interact directly with the technical infrastructure.

Research needs in this context are the creation of a commonly acceptable participation architecture spanning across many application scenarios, of suitable interfaces, and proper mechanisms to leverage patterns and intents announced by application platforms.

Near Video-on-Demand (NVoD) is a technique that allows to stream video to multiple customers in a similar fashion to Internet streaming services like Netflix or Amazon Instant Video. The bandwidth in NVoD is a priori constrained by the publisher of the content by distributing it over multicast channels instead of the one-to-one communication typically employed in VoD. However, in contrast to other broadcast techniques, in NVoD the audience watches the video from the beginning like in traditional VoD services. With this approach, users experience short delays before the reproduction actually starts. This solution is considered to be an interesting option to offer VoD in wireless channels thanks to the ability to serve VoD to multiple customers without increasing network usage.

Erasure codes are used in NVoD to guarantee the data integrity in the lossy wireless communication channel. Erasure codes have the ability to recover lost packets in temporal windows by receiving a subset of those sent by the content publisher. A small redundancy is here applied to guarantee the majority of the users achieve an acceptable Quality of Experience (Qo E) for video reproduction.

NVoD has been successfully tested and simulated in target scenarios like WiFi or WiMax. After two decades of evolution, NVoD is a mature technology and has been a recursive topic in the academic community for many years. However, there is no commercial solution exploiting NVoD. NVoD together with wireless communication techniques look promising because of the reduction in hardware cost as well as power consumption. The 5G should be able to provide the suitable work frame for NVoD over wireless due to increased spectrum availability and much higher data rates.

IV.1.3 : Business value & impact

The telco CDN infrastructure enables service providers to deliver premium video content (linear and on-demand) with superior quality of experience to paying subscribers. The video content can be delivered to any type of screen (smartphone, tablet,...). In addition to the delivery of video, service providers also want to use their telco CDN for the delivery of their multimedia-rich interactive Web applications. Hence, these CDN solutions enable operators to deploy multiple services in a cost-effective way enhancing their profitability, reducing the customer churn and accelerating the recovery of their network investments.
The telco CDN market is expected to grow by 12% per year according to Multimedia Research Group, MRG, 2012. Via extrapolation, the CDN market will reach about 2.8 billion Euro in 2023. This currently projected growth is mainly based on the increase in video consumption. The extension of the telco CDN use towards video-rich interactive Web applications can be expected to have a positive impact on the growth expectation for the telco CDN infrastructure business. The disruption in terms of technology for developing Web applications (HTML5) and for delivering Web applications (HTTP/2) may be the catalyst for content providers to move the delivery of their premium video-rich interactive Web applications to telco CDNs and away from traditional CDN providers.

IV.2 Interactivity

IV.2.1 : Definition
The interactivity is one of features to enhance the experiences to different end-users with diverse devices in heterogeneous connected networks, including human-machine, and machine-machine interactivity.
There are lots of different interactivity technologies in the processing chain of either the Eye-to-Eye or Mouth-to-Ear, e.g., voice command, sound synthesis, face recognition, augmented reality, etc. Behind this, it is high requirement on the content delivery.

Three factors should be considered for the interactivity research:

1) Instant response in interactivity.

For each user, instant response from the network is the most important decisive element to the interactivity experience. For example, when we put some smartphones together, to create an Ad-hoc network to playback a multi-channel song, the synchronization among different devices are critical to the experience, it is required that the latency should be less than 10ms among devices; otherwise, the artefact becomes perceptible.

2) Correct response in interactivity.

For each user, correct response from the network is one of decisive elements to the interactivity experience. For example, the automatic speech recognition (ASR) and related APPs are widely deployed in different smartphone; however, ASR is not the first choice when the user want to do some interactional operations (e.g., sending message, searching website, etc). The reason is that that the recognition accuracy is not high enough at this moment, especially in noise conditions.

3) High quality response in interactivity.

For each user, the response quality, such as the video resolution and the richness of multimedia content which been deployed in the response, is one of another decisive factor of the subjective experience in interaction interface. Taking the AR as example, if the response only been taken by text information, it is definitely not as attractive as the response on video and sound, but the bandwidth requirement for the later one would be also increased. For a life size AR use case by 8k resolution video, the bandwidth requirement would reach to 10GB level.

Some research topics regarding to the interactivity are listed below, and the requirements to these topics are also explained here.

Research topic	Requirement in experience
Automatic speech recognition/synthesis, and natural language processing	It is required that the machine should recognize the sound from the user correctly, understand the syntax accurately. It is the foundations of making the voicing input as the one of top choices in interaction between human and machine.
Augmented reality	It is required that the new solution should provide the user an ultra high resolution to guarantee a clear display under different physical conditions (light/dark, any surfaces, etc.) from mobile to life size use cases.
Synchronizations of heterogeneous devices (SC)	It is required that the new solution should remain a low latency among diverse connections and devices, even it is content sharing of ultra HD video or even holographic content. The rich experience can bring out additional benefit of increased social connections in future networks.

IV.2.2 : Technical feasibility

1) Automatic speech recognition/synthesis, and natural language processing have made big progress, especially the recognition accuracy can be beyond 90% even under noise conditions. The break-through in voice front-end modelling and application of new machine learning provide technical foundations to further improve the ASR accuracy in realistic conditions. Additionally, more cloud applications are adopted in the market to collect diverse and high quantitative training database to increase the robust of ASR.
2) Augmented reality
   To generate a good experience of reality-virtual fusion, it is a challenge to computational efficiency and attractive content provision. Currently, there are some mobile APPs in smartphone, which capture the picture in reality and synthesize augmented information on screen; it is attractive to customer, but limited immersive experience. Some optical see-through technology is dependent on the material and also strictly constrained by physical condition; on the other hand, the video see-through technology create another approach based on video synthesis with the help of promising progress in computing hardware.
   It becomes essential that AR applications in order to offer benefits in real-time and coordinated multi-source and multi-user contexts, they require low-latency communications systems. Especially in the mobile outdoor context, the future 5G communications needs to ensure near zero latency networking. Mobile AR applications may also require significant bandwidth in case the 3D models need to be quickly transferred between devices. Algorithms dealing with e.g. real object masking, may also require transmission of RAW images to servers for processing before views are sent back to client devices for viewing. Smooth movements may require such process to be performed at high frame rates, thus necessitating significant bandwidth.

3) Synchronizations of heterogeneous devices
   Except for the human-machine interaction, one attractive scenario is the interaction between different users remotely. One challenge is the synchronization with very low latency; the Ad-hoc networks could support easing network creation, information exchange between devices, and even the recovering mechanism. Currently, some commercial solution is available which can realize the synchronizations with low latency, e.g., group playing and sharing music. The next step is the low-latency synchronization of different contents among different devices, including but not limit ultra HD video or holographic.
4) Cyber-physical systems (e.g. exo-skeletons)
   Those are new types of components that might extend the capabilities of human bodies with additional senses etc. Such systems that have already been experimented by e.g.

Stelark[2], Marcel-lí Antúnez Roca [3], Kevin Warwick [4]etc. show potential for such systems to be networked with remote systems and similar devices work by other users. Such devices require reliable communication and preferably zero-latency communication.

IV.2.3 : Business value & impact

With new technology, the enhanced interaction will bring additional experiences. With break-through on the voice-based information input, and the augmented reality application, the usability of the interaction will make a big progress. It will help to generate high quantity of connections, and the requirement on content transmission, content scalability will also be increased accordingly. It's not only the bandwidth, but also the very low latency, the latter one will result in a reshaping of current network.
The AR applications have recently started moving away from desktop based ones to mobile ones. New AR software development kits (e.g. Mobile SDK from MOMIRAS project[5]) offer capabilities of developing custom applications for e.g. mobile phones allowing users to use/play with them in any environment, e.g. outdoors. This is a significant move in terms of business opportunities for e.g. SMEs and also large companies, as well as service providers to offer new types of mobile service provisioning in terms of larger bandwidths, wireless communication, increased reliability in terms of latency and response times etc.

IV.3 Content security

IV.3.1 : Definition.

Information Security (IS), which includes Content security, is one of the most complex issues that organizations must deal with, in any networked environment. The challenges they need to face include compliance to regulatory requirements, business decentralization & mobility, reliance on web and smart phone technologies, and an increasing number of new threats & security-unaware users.

The services and technology solutions offered by telecommunications manufacturers and service operators are designed to address the business security issues primarily related to the provision of resilient connectivity solutions. Within a mobile network today, the provision of mobile connectivity services is somewhat bounded by the perimeter of the commercial barriers of the service or network provider. User Identity in this case, is primarily used for the availability of service and for associated user billing.

Next generation information services, especially considering a 5G view, will spread across multiple mobile network services providers and traverse a number of cloud based transformational services (routing, transcoding, etc). As such, we move from a world of human managed information, to a more rich offering of services which may carry and transform our information

A unique approach ensures the trustworthiness of information under the umbrella of a secure seamless information environment, in full alignment with core business requirements.

Conventional perimeter security solutions are no longer considered sufficient in a highly dynamic and contextual networks. Network providers need to be committed to assist their information based customers in responding to increased new demands, in particular, in the following major areas:

- Supporting both resilient transport and support for informational based security;
- Security Information & Event Management;
- Continued support for new modes of Web and Email Security (dnsec, etc);
- Network Admission Control.

Benefits include:

- Establishment of proper security posture to mitigate risks and facilitate growth;
- Assured business continuity while providing the basis for an efficient and secure deployment of new services;
- High-quality results with low TCO and high performance;

[2] Stelark: http://stelarc.org
[3] Marcel-lí Antúnez Roca: http://www.marceliantunez.com
[4] Kevin Warwick: http://www.kevinwarwick.com
[5] MOMIRAS Project: http://www.momiras-project.eu

• Proofing all valuable business assets under the umbrella of a secure, seamless environment. Supply chain security is especially concerning;
• Reducing capital and operational expenses required for the acquisition and maintenance / administration of a security product.

Figure 1 identifies the various stakeholders in the NEM environment, the relationships between them, and the motivations and requirements on valued assets. All require protection by NEM security mechanisms, functions and facilities. The relationship between the stakeholders are characterised as B-B – business to business, and B-C – business to consumer.

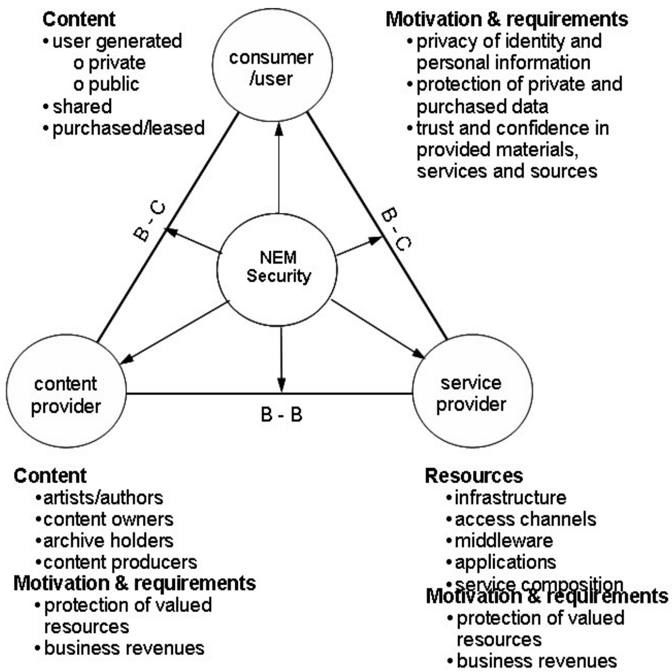


Figure 1 - NEM Stakeholders and connection with Security

When talking about the security of NEM, the three stakeholders identified are the consumer, the content provider and the service provider. In the NEM environment, the consumer can in fact be both a consumer and a producer of content (sometimes referred to as a "prosumer"), and may have data and content in the public domain as well as maintaining personal data in a private space. The content provider in this diagram represents professional owners or producers of content, who deliver content to the consumer via a service provider, whilst maintaining a direct relationship with the consumer for contractual purposes. The service provider(s) will support the delivery mechanism that may include (as it does for many mobile phone operators today) the consumer's access device. The service provider(s) will also provide the necessary operational middleware and applications. It is important to note here that there will often be multiple service providers, including those providing connectivity to both the content providers and prosumers, but potentially also other services such as content aggregation, and provision.

The security requirements cover the needs of each of these stakeholders – consumers wish to protect their privacy whilst the content providers and service providers want to protect their respective business interests – but it should also be recognised that the security requirements also cover the protection of the relationships between each of these entities.

This gives an indication of the fundamental security considerations and requirements, rather than the techniques used to implement security. Whilst we should accept that this is rather basic and perhaps incomplete, it identifies that there is considerable initial work to be done in the modelling of the security environment, addressing the needs of the stakeholders themselves, and the relationships which exist between them. This exercise should be performed as an NEM and NetWorld2020 combined activity, in order to design effective mechanisms by which such an environment is ultimately secured. As shown in the figure, contained within the central 'security' element will be the generic influencing factors such as legal/regulatory issues, security technologies, contract/relationship creation and management, rights management, identity management, trust (including user confidence), authentication, authorization and intrusion detection and isolation. An approach to consider everything that we might associate with trust and security (including but not limited to all those elements listed above) and then view this as a security 'resource' from the point of view of each of the stakeholders and their relationships (i.e. look back along the arrows in the diagram). The requirements of each of these points-of-view can then be identified and investigated according to their relationship to the overall security resource. So, for example, issues such as personal privacy or simplicity of interaction with the security system are viewed from the consumer's perspective, whilst protection of personal financial data or secure connectivity are viewed from the perspective of the B-C relationship.

In addition to basic requirements for security, privacy and trust between the NEM stakeholders outlined above in figure 1, the security and availability of the network and service infrastructures in relation to the NetWorld2020 stakeholders must also be protected against breakdown and malicious attack, with an initial listing of research challenges highlighted below:

- Security, trust, and privacy solutions for NEM must be scalable: all the aspects of security – authentication, access authorization, key management and distribution, message integrity, accountability, non-repudiation, etc. – must be cross-considered with the various facets of scalability (i.e. with respect to sizing, performance, capacity planning, stability, etc.). Scalability also has "horizontal" inter-relationships with other concepts, such as QoS, dependability and resource management;
- Availability of content anytime, anywhere, any device;
- Trusted services and applications - simple, secure, fast, and reliable;
- Full user control and awareness of what data can be available in the context-aware environments in which ubiquitous, user friendly services are based on real user requirements and needs;
- Digital rights-management / protection technologies across the entire value chain for complex, composite polymorphic infrastructures;
- Regulatory aspects with respect to protection against unwanted material, attacks, denial of service, intrusion, misuse, etc.;
- Consistent mechanisms and functionality for security of networks and security that are universal, transparent (visible), understandable (easier and more natural), easy to use, effective, revocable (by all parties) and accessible;
- Privacy aspects – Privacy by Default, Privacy by Design, ease of use etc. of identity management systems[6];
- Effective controls (e.g. parental controls) over access to unacceptable content;
- Trust measurement and management methods, e.g., reputation;
- Maintenance of confidentiality by business associates, and integrity in their handling of business issues – in particular payments; without this confidence and trust, no viable business is possible;
- The concept of Digital Assets represents much wider implications than information management in general: it includes management of Intellectual Property Rights (IPR), Digital Rights Management (DRM), copyrights and online sharing of information. The security objectives related to the digital assets bases are in terms of confidentiality (non-disclosure to unauthorized persons), integrity (non-alteration of content, accidentally or maliciously by intruders) and availability (the availability of licensed users to use these assets without being hindered by unintentional or malicious acts).
- Content Ownership, licensing, transfer must be provided in a non-ambiguous and transparent manner, in which there is no doubt as to the provenance (place or source of

[6] A good starting point for this topic would be the FP7 Prepare project - http://pripareproject.eu/

origin) of the content and clear ownership of the content, which could then be licensed and/or transferred by the owners.

IV.3.2 : Technical feasibility

Information Security Management aims at assisting customers to understand why, what, and how to spend on security. The most important characteristics, per service / solution offering, are given below:

- Information Security Strategy Services

Services to assist customers in the establishment of an adequate and robust security organization, alignment with business requirements, and formalization of the necessary security roadmap to mitigate security risks.

- Information Security Engineering Services

Technical services intended to re-engineer the customers' infrastructures in reference to information security, assess the security posture and provide support throughout the information security lifecycle management.

- Network Security Solutions

Technologies for protecting the corporate infrastructure and Data Centre against external and internal attacks.

- Systems Security Solutions

Sophisticated technologies intended to protect systems & endpoints, and provide the means of controlling and monitoring security related incidents on a continuous basis.

- Application Security Solutions

Technologies for protecting critical web applications, Internet access and corporate e-mail communication.

In terms of technical feasibility in content security related to ownership and authorization, we must address the security of the multimedia contents. These include the following security solutions:

- Multimedia Security Solutions

Technologies aimed to increase the trustworthiness of multimedia data by providing means for securely assessing the ownership and authenticity of the content in multiple scenarios (multimedia data transmission, multimedia data playback, etc.).

- Advanced DRM Solutions

Technologies intended to control and manage the rights to access the multimedia content, and provide the means for device and end-user identity verification. The inclusion of metadata to provide security-related information must be complemented with end-user authentication in order to ensure that content is only accessed by authorized users. In fact, both user and device authentication shall be addressed in order to guarantee end-to-end security. Regarding the end-user, the development of biometrics-based authentication algorithms (e.g. face or signature verification) and its combination with improved device authentication methods, shall allow a secure content delivery and the enhancement of current DRM (Digital Rights Management) solutions.

- End to End (E2E) Security Solutions

E2E security means that sensitive data is encrypted all the way from the device side application back to the enterprise. Rather than relying on transport-level security (such as Secure Sockets Layer, or SSL), end-to-end security puts the power of strong encryption in the user's hands, all through a simple interface. In simple terms applies to situations like where e.g. device A passes a message to device B which in turn passes a message to device C. End-to-end security is security which applies across the entire chain from A to C. If we consider SSL, it is a transport-level security protocol, so it could offer separate security between A and B, and security between B and C, but not between A and C. That is, the A to B security is entirely separate from the B to C security. The end-to-end security resolves the so-called “air gap” where sensitive data was previously decrypted at the gateway during translation for wireless protocols into Internet protocols.

All of the above describes the technology based solutions from different perspectives. In fact, the majority of discussion to date with regard to 5G is technologically focused. Consequently, there is a significant lack of consideration for the next generation applications that could use 5G, and this is a key objective of this joint working group. Is it about more video services, multi-angular view 3D TV, distribution of 3D printing data? We need to brainstorm about the next “killer application” for which the 5G KPIs address for content and what is the technical feasibility in relation to security solutions that needs to be addressed by the NEM/NETWORLD2020 communities.

Areas of our society that develop much slower in terms of communication capability are those which exist within much smaller scales of economy than the consumer market. Communication technologies that support Public Safety and Disaster Relief (PPDR), or Critical National Infrastructure are left behind in environments of limited budget and long cycles of technology refresh.

The widespread consideration to use common-off-the-shelf (COTS) technology attempts to redress this economy of scale. Markets are currently attempting to repurpose consumer technologies for provision of more capable wireless and networked applications that are considered critical for the safety and security of our society. This re-purposing can surely benefit our critical services by inheriting the low cost and technological maturity, which has been driven primarily from the consumer market.

With the current day consideration to adopt COTS in critical communication applications and the economic rationale behind that, it is likely that this will continue long into the future. It is highly unlikely that bespoke technologies (such as TETRA), will be developed specifically for individual market purposes. Therefore, future considerations for 5G will likely be adopted by many more than the consumer market. The evolution of 5G should already accommodate such application spaces. Some work has already been accomplished to consider this[7]. In fact, 3GPP is currently ‘uplifting’ the 4G standards to include capabilities to support mission critical communication applications[8].

Among many, there are two distinct criteria that are commonly cited as high level requirements for 5G:

a) Creating a secure, reliable and dependable internet with zero perceived downtime for service provision;
b) User Controlled Privacy[9]

Considering just these two criteria and the discussion given above with regard to our fragile internet, and the need to support mission critical communication, we uncover a significant distinction that should advise on the approach to assure the security and resilience of 5G infrastructures and the information services using it.

The first criteria a) relates primarily to the resilience of the 5G infrastructure. By definition, resilience is a measure of a systems ability to retain its originally intended performance after being compromised. Compromise in terms of 5G infrastructure could affect the wired and wireless communication bearers, the virtual components or the physical networking and virtualisation hardware. Resilience of the data transfer carried by the 5G infrastructure is also considered here.

The second criteria b) relates to information. Information is considered separately here but somewhat linked to the consideration of data in the first criteria. Information represents the meaning of data; the facts that the data represents; the value that the data has once used in the context of it purpose. Therefore, the information carried by the 5G network must be protected in its own context, and not necessarily rely upon the infrastructure that carried it.

Protecting the 5G infrastructure and protecting the information poses different but linked challenges. In our current fragile internet, our mobile technologies assure who is using the mobile service for

[7] http://www.networks-etp.eu/fileadmin/user_upload/Publications/Position_White_Papers/NetWorks_White_Paper_ICT_CritNatInfra_Final_12-07-02.pdf
[8] http://www.3gpp.org/specifications-groups/sa-plenary/sa6-mission-critical-applications
[9] http://www.v3.co.uk/v3-uk/news/2371386/5g-will-underpin-the-internet-of-things-but-security-fears-must-be-overcome

the primary purpose of addressing and billing. Information carried over the mobile service is protected separately. One could question whether over-the-air encryption is required for network data payload, or is it just required for protecting network control information to safeguard the resilience of the network.

It could be considered that the two criteria, a) 'network resilience' and b) 'informational privacy' given above, could be isolated problems to solve. In fact, this is not the case. With this discussion, we only scratch the surface of the problems of security and resilience of future 5G technologies. These elements are intertwined in an ever increasing, complex multidimensional array of trust.

Such questions can be posed, such as:

- Can the software (e.g. virtualised components) trust that the hardware (and hypervisor) will do as it's told?
- Can the hardware (e.g. software defined radio) trust that the software will operate within acceptable parameters (and not transmit illegally)?
- Can the provider and/or consumer of the information trust the network components over which the representative data was transferred.

Error! Reference source not found. attempts to illustrate the greater problem of trust between the components of the 5G environment. This diagram is greatly simplified as this doesn't include the different organisations which may own and/or operate each of the different components of the system. Supply chain security, is therefore, also of key concern for the NEM/Networld2020 communities.

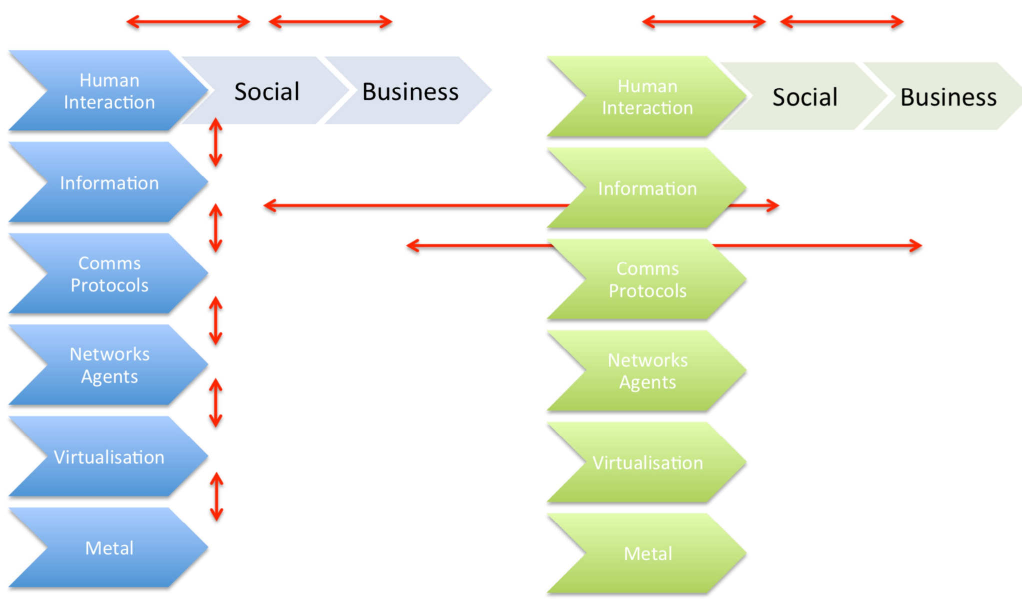


Figure 2 Who trusts who ?

IV.3.3: Business value & impact

In order to maximise business value and impact, it is crucially important to have a global view on security, privacy, & trust over open and standardized networking infrastructures. In today's global and mobile economy, it is common to hear stories of companies paying significant costs and exposing themselves to lawsuits due to corporate assets and data being compromised. At the same time, IT departments started to face new risks associated with the growing need to support remote access to mobile users, partners, and customers. Administrators must constantly compromise the risks associated with providing remote access with increasing demands for mobility. Remote users require access to company's resources from anywhere and at any time, using any computer whether it is provided by a company, own laptop or an internet cafe PC, mobile or handheld PDA device. IT departments face the challenge of allowing access to growing number of mobile employees and partners, supporting their variety of devices and networks, facing responsibility for ensuring that company's data is safe from viruses and malware, disgruntled employees, home-grown and professional hackers, or compromised devices that might trigger malicious threats on companies' applications or its entire network. Vulnerable security gaps in a remote access solution can lead to costly security incidents and public relations nightmares, if a right remote access tool with the best end-to-end security isn't in place. A rapid growth of the number of networked Internet of Things compliant objects opens new avenues for a novel breed of security breaches, data high jacking methods and other security risks. Extreme miniaturisation of the majority of IoT objects might require compromising cost/size for relaxation in network security, leading to increased security risks.

Content security is crucial to enable most business models of network-based content providers, since ownership and authorship must be traceable to enable billing, and protection from unauthorized access is crucial to enabling the monetization of media.

IV.4 Network capabilities

IV.4.1 : Definition
In order to share or distribute Content and Media, and satisfy users' expectations (for example, contents should be available on all their devices, with high quality, and immediately at any moment) It is necessary to design or improve a set of network capabilities that will make this possible.

The higher bandwidth and lower latency that will be provided by 5G Networks are clearly key elements to achieve those objectives. Nevertheless, there are other advanced techniques that can be applied to content and media distribution that will contribute to provide the desired experience to users while maintaining the costs at a reasonable level. For example:

- Content caching: The Network keeps copies of the content close to the users that are consuming itreactively (after some users request the content) or proactively (even before there is a high demand, for example taking into account predictions based on location, user profiles or events)
- Multicast distribution: The Network sends the same stream to multiple users, and only replicates it when necessary. It should be possible to change from multicast to unicast (and vice versa) with an optimized transition and making it completely transparent to the user
- Link selection: Nowadays, user terminals are equipped with several communication interfaces and protocols, and it is possible to choose which one should be used at any moment, or even combine them. For example, it would be possible to use or combine:
  - License-free technologies (WiFi, Zigbee, Bluetooth Low Energy, etc.)
  - Standard cellular networks (LTE)
  - Device to device communications (LTE D2D)
  - Wired connection (fibre, Ethernet)
  - Broadcast (DVB-S, DVB-T)
- Traffic classification: It is possible to adjust the Network to optimize the performance for the traffic that requires a higher QoS. This includes the management of Human-Type Communication (HTC) and Machine-Type Communications (MTC), which pose completely different requirements that must be handled at once.

Nevertheless, to decide when and how those techniques should be used, it is necessary to have information about the traffic (that is, about the different services and applications, the flows and their contents), and about the users (where they are, what will they demand, etc.)

- Content awareness: The Network can recognize the different flows, and to which service, applications, and/or users it belongs. A content aware network will be able to apply the different techniques presented before:
  - Content caching: Popular contents are identified and cached.
  - Multicast distribution: When the same content is consumed by different users, it would be possible to use multicast techniques (making it transparent to the user).
  - Link selection: The network can apply policies to use the optimal combination of communication interfaces to provide the best quality of service for each content. For example, a videoconferencing will require an upload channel with enough bandwidth available.

- Traffic classification: Streamed contents will require lower latency and higher quality than other classes of traffic.

- Location awareness: Service provisioning based on position, location, and movement of devices provides context to the Network to make decisions.
  - Content caching: Store contents before a user who is demanding them in another area arrives.
  - Multicast distribution: Decide to change to a multicast or unicast technique depending on the number of users in an area.
  - Link selection: Offload one link in order to make room for new users that will arrive soon or prepare for a disconnection in one of the interfaces.
  - Traffic classification: Launch a graceful degradation before a user moves to an area with poorer coverage.
- Context awareness: The location is one of the main parameters that provide information about the context. Nevertheless, there are other parameters that should also be considered, such as:
  - Presence.
  - Device capabilities.
  - Cost of the service.
  - User personalisation (according to user preferences or to adapt the quality of the content to the user's perception capabilities).
- Demand prediction: An estimation of the contents that are going to be requested minimizes the risks of downtime and poor performance.
  - Content caching: Contents can be cached proactively (e.g. a viral video or a new film).
  - Multicast distribution, link selection: The Network can decide to use multicast or even broadcast when a content is going to have a high demand.
  - Traffic classification: It would be possible to launch graceful degradation for traffic that is not critical when it is expected to have bandwidth problems.

IV.4.2 : Technical feasibility

Software Defined Networking (SDN) is one of the key technologies for achieving the objectives proposed for 5G Networks. SDN is an emerging paradigm in network management that decouples the network service (control plane) from the underlying physical infrastructure (data plane). Thus, the network controller becomes a centralized and programmable element. The main advantages of this architecture include the ability to extend and develop new functionalities and the capacity to control the whole network in a centralized fashion.

Therefore, SDN is a cornerstone for the implementation of the different capabilities that will provide the Network, especially in a context where the amount of data to be exchanged, the diversity of players and devices, and the new quality of service requirements generated by content distribution networks originate several challenges for network management and resource allocation. The software installed in traditional home gateways, edge routers, or other network elements, made extremely challenging to introduce new features or to modify their operation dynamically. But, following the SDN paradigm, enabling a central controller to make traffic engineering decisions and pushing rules to the different network elements to enforce such policy greatly increases the flexibility of network management. It is possible to build a management system that reacts to various conditions of the network. For example, one possible direction is to perform traffic shaping based on content requirements or performance measurements. Another example is proactively prefetching and caching content into the home gateway or a network element, even before the last mile. SDN can be also helps to optimize telco networks for content centric networking by actively instructing the data plane and the packet forwarding of the switches according to the given status as well as decide which content is going to be cached, disseminate information about location of contents, redirect flows to the new location of the user, decide to use a multicast or unicast protocol, etc.

SDN moves the intelligence from network elements to a central controller, creating a Network which is not only reactive as is now happening. Current networks react to changes in demand or quality by changing the way they provide services, with reactions that can be very focused and microscopic (e.g., a TCP sender adapting its sending window). These reactions happen either on very short time-scales based on relatively accurate information (TCP congestion control, wireless schedulers in LTE base stations) or on long time-scales like the circadian rhythm, based on highly average information. The middle ground – a few seconds to tens of seconds or minutes, based on only modestly accurate information – is largely unexplored. Yet for this middle ground, promising results exist, partially from data centres, but in particular from multimedia applications like video streaming. With plausible assumptions on knowledge about some seconds into the future – both with respect to network and user behaviour – considerably QoE improvements are possible. For these improvements, however, anticipation of network and user behaviour needs to be available, and SDN controllers and applications can help to provide such information. Nevertheless, this is an open research field, where new architectures, interfaces, and protocols should be studied. Additionally, there are relationships with topics like content popularity that should be analysed to optimize the usage of networks (e.g.: how likely is a particular user to watch a particular video clip indeed to the end?).

Original contents have to be stored, protected (backed up), and finally replicated near the consumer in such a way the data can be retrieved when necessary. The local resources cannot be sufficient to store historic copies of digital data that usually grow fast (e.g. multimedia content), and then, cloud storage services become essential. Furthermore, the quality of the contents, and the space required to store them, is continuously increasing. It is also important to provide mechanisms that protect the access to the contents from unauthorized parts. Both problems can be solved by combining encryption with deduplication mechanisms. The former introduces overhead, but the latter avoid sending or storing data fragments that were already sent in previous copies.

Most of cloud providers offer highly durable and available storage for a variety of content. Consumers usually pay for the resources they use (storage space, bandwidth usage, CPU, memory…), so they can decide how much time a copy must be stored. In this context it is important to give the customers the appropriate tools to manage their data, avoiding manual procedures that can require interaction with the provider.

The location of the user will have implications on how contents will be delivered. Therefore, it is necessary to devise new methods for positioning and location of communication devices which can overcome the current limitations of Global Navigation Satellite Systems (GNSS)-based services. In particular, novel mechanisms must he sought to avoid the current poor capabilities in indoor environments and high energy consumption profiles which drastically reduce the battery lifetime of devices when positioning systems are in use. Instead on an “added capability” on top of the network infrastructure, the provision of location services should be conceived from the scratch, since current signal modulations jeopardize the location accuracy that can be attained with methods based on the signal propagation time. The provision of assistance data for user equipment positioning (radio frequency fingerprinting, assisted GNSS) and the evolution of the Secure User Plane Location (SUPL) and the Open Mobile Alliance (OMA) extensions, as well as establishing proper privacy policies, will be instrumental in achieving network-based, anywhere/anytime, accurate, robust and reliable positioning.

Nevertheless, even knowing the user location, it is not always possible to predict her or his new position, and guarantee a permanent connectivity. In this case, content distribution networks can benefit from the combination of traditional backbone network connectivity and what has been called Delay- and Disruption-Tolerant Networking (DTN) protocols. These protocols provide the means needed to transmit information in partitioned, mobile or (in general) challenged network environments, dealing with problems arisen in communications channels such as high and variable delays, link disruptions, predictable and unpredictable node presence, etc. The usage of DTN architectures and protocols, or other alternatives such as LTE D2D, will allow to provide network connectivity when backbone infrastructure is not available, by using peer devices as data relays, or even to reduce the load of the backbone network infrastructure by using direct connectivity between devices to distribute information that has lower real time restrictions. Moreover, DTN communications can be used to efficiently provide context-dependent information, offering the possibility of creating context-aware services directly supported by the network infrastructure and at the same time optimizing network resources.

In other situations, it is possible to detect that a link is going to be saturated, or even that the user is going to lose coverage. In that case, it is possible to use Data Offloading to deliver data originally targeted for other network technologies, especially for cellular, over WiFi networks. In conditions of congestion (due to high concentration of users or users demanding high capacity), low coverage or simply low capacity or data rates networks a user can experiment low QoE and QoS and even the interruption of the service. A traffic offload over a WiFi network can solve these problems and offer service continuity and improved QoS/ QoE to users and allows load balance between networks. WiFi offload will be especially relevant for video/audio streaming and online games traffic.

IV.4.3 : Business value & impact
Users' expectations to access high quality content has to be satisfied, but at a reasonable cost. A correct design of the network will achieve both objectives, for example, through the usage of caching mechanisms and multicast protocols in order to reduce the resources required in the core network to distribute the different contents.

The SDN technology will be also essential. The control plane separation of SDN will allow deploying commodity switches based on merchant silicon, instead of purpose-built, proprietary appliances, which results in lower CAPEX. On the other hand, SDN provides an automated, comprehensive, and flexible configuration, which, coupled with centralized control and management, results in lower OPEX. The horizontal architecture of SDN improves interoperability while fragmenting the market by increasing choice at the hardware, controller, application, and orchestration levels, creating chances for startups and emerging business models based on new SDN network applications.

Cloud storage technologies installed in the core and the edge of the network will be also essential to provide a place to keep copies of the contents that are distributed. When the contents are generated by the users, it is also important to provide mechanisms to keep the information safe and secure. Cloud backup services provide scalable and durable ubiquitous storage.

IV.5 Content popularity

IV.5.1 : Definition
The economic sustainability of the sites hosting Web content is strictly related to the deep understanding of the popularity evolution patterns of the content and of the hot topics. Early detection of popular Web content in the Internet can allow publishers to maximize their revenues through better ad placement. Moreover, given the ever-growing consumer Internet traffic, content distribution networks can rely on popularity prediction methods to proactively allocate resources according to the future users' demand. Timely predictions for Web content characterized by a very short lifecycle present a real challenge: news articles quickly become popular and "die-out" within hours. News quickly become outdated, while on-demand videos are still found long after they are made available through VoD Service Provider. YouTube keep attracting views throughout video lifetimes and provide programmatic APIs access to several video statistics, such as view count at a given time or complete history of the view counts for each video during its lifetime or criteria driven statistics "most commented", "most viewed" across all submitted videos.

Internet allowed many players, even mere consumers, to become creators and distributors of content but also intensified the competition for users attention, since only a small number of contents become popular while the rest remain in Long Tail or even completely unknown. User attention used to be allocated in a way that few content receive the most attention, whereas most content get only some views and downloads (Short Head and Long Tail). The ease of producing and delivering online content highlights the complexity of users attention: monitoring, allocation, prediction. Traditional media consumption patterns already changed moving user attention away from linear broadcast TV towards on-demand online viewing based on unicast delivery often on the move. Thanks to the ubiquitous Web 2.0 applications and services, producers can reach audience, possible on a global scale, exchange and interact with them in number of ways: through video, photo, and music sharing; blogs, wikis, collaborative portals, news aggregators, whereby content is submitted, rated, and discussed by the user community.

IV.5.2 : Technical feasibility
Users attention will be very important factor in the future scenarios based on Converged, Connected and Interactive media, involving internet, phone, TV, mobile and content (in music,

video, gaming, … etc) together with seamless access to content on high speed networks (wired and wireless). The same content can be available through several Service Providers and through different communication networks and using various devices.

Users attention is spread across multiple domains and various types of contents (professional and user generated videos, news article, comments, photos) often published on social networking services, the most popular platforms to share information and accommodate users' participation. So, there is a need to design accurate metrics, methods and algorithms that can extract and cross-correlate information related to content consumption from different network and platform domains delivering content across a range of devices and environments.

Content and Service Providers can provide to an application, regularly or on-demand and even in real or near-real time the number of UEs presence on certain content without violating user's privacy. Real-time QoS may for example allow video applications to adjust UL/DL video bit rates to improve streaming experience. An application can provide to Content, Service or Network provider expected or predicted content popularity, regularly or on-demand or even in a "push mode" that could be used in order to optimize content service and/or content distribution.

Information coming from different sources and domains, such as from several online social networks as well as from services hosting the user generated contents, could be taken into account in order to make accurate prediction. Yet, the definition of techniques for detecting popular content across multiple domains is challenging (those source of information could not be available at disposal for every content, thus raising the issue of building models with lacking data) and a viable alternative could be represented on tailoring a technique for a specific source of data (e.g., by modelling the content popularity growth as a pattern analysis problem). The first category is represented by mechanisms that take into account information from multiple domains for their prediction. Several external factors have been shown to be correlated with the estimation of popularity evolution of videos, such as the number of users' subscription to a given YouTube channel, the referrers that lead users to videos, user comments and user voting behaviour. The second category is represented by mechanisms that perform prediction based only on the observed domain. These methods only model a user's past behaviour or an item's history individually, and do not account for external (e.g., social) signals.

Modelling the measured access to the content (such as accumulated votes and/or views of content,.) it could be possible to predict the future dynamics of content consumption, without considering the semantics of popularity and why some content become more popular than others. However, semantics of content popularity may be used to predict user acceptance rates in the absence of early-access data. Capturing trending topics and learning how to include them in prediction models can improve the prediction accuracy. Understanding and merging user activity considering different channels (e.g. Social Networks, Search behaviour) could provide important insights about the popularity of certain topics.

IV.5.3 : Business value & impact

Content popularity should be used not only to better understand the dynamics of content consumption but also to improve various services. Observing content popularity dynamics and predicting the popularity of content is useful in many areas such as network optimization (e.g., caching and replication), online marketing (e.g., recommendation systems and advertising), or even revenue outcome prediction (e.g., economic trends).

Observing content popularity dynamics should be done without violating user's privacy. Moreover new business models, rules and principles could be designed and established regarding measured or predicted content popularity data: owner, rights to use and publish such data, business models, business intelligence.

Accurate content popularity monitoring and predictions can prove valuable to different actors and can be used as a tool for better content service organization and effective content delivery. For example:

• organization of highly dynamic content pool (such as online news) - instead of relying on human editors (a practice that is still present nowadays), it is possible to refine organization

through automatic solutions using online and near real-time content popularity metrics and methods
• optimizing large-scale caching infrastructures - depending on how accurate one can predict the future users' demand: which content will be popular, its geographic locality of interest, the amount of attention that it will generate; content popularity dynamics can be used to design more scalable content delivery solutions that proactively organize content delivery according to the future users' demand.
• optimizing mobile delivery - operators can optimize network systems taking into account macro and micro traffic characteristics (including content popularity metrics), aiming at optimal use of various technologies (cellular, terrestrial broadcast, satellite);
• search engine results – including content popularity metrics and prediction the outcome of a search query could prioritize future popular content over expired one or over less popular one; end-users can filter and find, more easily, the right content for them;
• optimizing advertising – advertisers can design more effective advertising strategies based on content popularity (even real-time) metrics across various services and platforms, focusing on a content during its popularity peak and putting less or no resources on expired items.

IV.6 Content Lifetime

IV.6.1 : Definition
Content providers including UGC and IoT Generated Content has a requirement regarding the duration of content availability in the networks. Most of the networks use cash mechanism in order to provide better QoS to end users but this content has to stay under the control of the content providers. For that reason, content provider should tell the network what has to be the duration of the content in the network. This parameter has to be passed to the network, so it will be able to withdraw it exhaustively at the end of the duration

IV.7 IoT content

IV.7.1 : Definition
Data coming from sensors/actuators of any device should be considered as content and most of the content/media companies are more and more interested to get this data for their application (a sensor is a content provider).
As far as these devices are connected to the network (heterogeneous connectivity), content aggregator (broker) should be interested to get this information in a simple way using a specific API which facilitate to access to a particular device.

Two aspects should be addressed :

- Connectivity : how to reach a specific device
- Service Discovery : what are the capabilities of a specific device, which language/protocol

IV.7.2 : Technical feasibility
[Connectivity]
There are several connecting networks for IoT with specific addressing plan and there is a need to help content brokers with an easy mechanism allowing them to address any device whatever and however it is connected.

[Service discovery]
The implantation of Internet of Things technologies has caused that the definition of content provider needs to be widened. Although this concept included in the past mainly multimedia and other types of structured data sources, with the increasingly amount of devices that are expected to be connected to networks in the future, new content provider types will arise. Most of the relevant information will be provided by distributed nodes equipped with sensors retrieving context information from their environment.

Ideally, other nodes in the network such as a content broker or aggregator should automatically know which type of content (service) is offered by content providers in order to increase manageability and automation. Several approaches have been used for several years inside traditional LAN networks with this purpose; DLNA for multimedia content or the more general UPnP set of protocols are good examples. Nonetheless, sensing devices will typically use communications technologies with constrained capabilities in terms of several relevant parameters like bandwidth or latency (6LoWPAN, ZigBee and other) and they will have also low power and computing limitations. Research has been done in order to devise a specific methodology for service discovery in constrained environments but no final consensus has been reached in order to integrate these concepts with widely used technologies such as UPnP or AllJoyn. Specific IoT designed service discovery methodologies will facilitate content distribution and classification with automatic procedures based on context parameters while also increasing network scalability and manageability.

IV.7.3 : Business value & impact
IoT business will become in the future a huge market and there is a need for the networks to provide an environment facilitating the access to devices.

IV.8 ATAWAD

IV.8.1 : Definition
Nowadays, users own a wide set of connected devices, ranging from the traditional desktop computer or the laptop, to relatively new devices such as smartphones, tablets, smartwatches or connected TVs. Consumers are becoming used to have ubiquitous access to their information, and they expect it to be available at any time, in any place, and using any of their (or even other's) devices. This is especially true for their personal information, but also for applications (users want to use the same application in the computer and in the smartphone, and have access to the same data, but they also want to launch an application in a smartphone and view the content in a big display or project it in a screen), and for media content. An example of the latter case is the popularity of TV streaming media devices (such as Slingbox) that became popular in 2005. This kind of devices allowed users to view and control remotely (from a PC, smartphone or tablet) their cable or satellite TV. Nowadays, "TV Everywhere" systems allow customers to watch their subscribed channels across multiple platforms (TV set, smartphones, tablets…), and anywhere they have Internet connectivity.

IV.8.2 : Technical feasibility
The 5G communications environment is being designed to provide high bandwidth, low latency and QoS capabilities. In such scenario, it will be possible to transmit high quality contents to **anywhere**. In addition, the new cloud storage services make it possible to store contents to consume them later, or at **any time.** Finally, the new connected devices are powerful enough to display any kind of content (e.g. next generation smartphones are able to reproduce 4K contents), and even if this was not feasible, it is possible to use cloud services to transcode the contents (even in real time) and adapt them to the quality and size of the screen of **any device** used to show the content. 5G networks will make it possible to implement this scenario even for Over-the-Top (OTT) players, but thanks to the use of technologies such as SDN or IMS, it will be possible for service providers to guarantee a QoE to their customers, offer higher quality contents, and include value-added services.

Nevertheless, users are not only demanding to have access to their information, applications, and contents from different devices, in different places and at any time. They also want to combine their devices and use them together to satisfy their needs. This is closely related to the Activity Oriented Computing (AOC), part of the ubiquitous computing approach. This paradigm provides solutions in a user-centric approach, composing and deploying services to satisfy user demands. This way, it is possible to play a content that is stored in a smartphone in a TV, or simply ask the TV to start playing a content that is stored in the cloud or streamed by a content provider. Another typical user request is to be able to transfer a videoconference, which was started in the smartphone, to a more appropriate device (a computer, a TV with camera, etc.), or even to use peripherals from different devices to make the conversation more comfortable (a webcam connected to a PC to capture de video, a projector to display the partner, and a high quality set of speakers and microphone to capture and reproduce the audio).

Protocols such as Miracast (based on Wi-Fi Display and Wi-Fi direct, that in turn, use other standard protocols for basic functions such as device discovery or IP configuration) solve part of this problem, but there are also more advanced works that are addressing this scenario, for example H.325. This is an ITU-T initiative (also known as Advanced Multimedia System, or AMS), that started as an evolution of multimedia protocols such as H.323 and SIP. It is an advanced architecture that supports distributed media applications that involve multiple personal and public devices. The objective is to advance beyond traditional telephony systems, and make it possible to build complex communication environments where users make use of several devices during a session. For example, as said before, a user could start a voice call with his phone and add the input video stream from a fixed camera situated in the same room, send the video and audio stream from the remote peer to a TV and even share a document or an application being executed in a mobile computer. H.325 assumes that every application may exist as a group of distinct components that may be physically separated from the user terminal, and in consequence the ITU-T H.325 work group is defining the components and interfaces to make this possible. The user terminal (usually a mobile phone), will coordinate the network elements and the communication between peer applications (components) and will be the element responsible for establishment and teardown of communications.

[WiFi Offloading]

WiFi Offloading is a paradigm to deliver data originally targeted for other network technologies, especially for cellular, over WiFi networks. In conditions of congestion (due to high concentration of users or users demanding high capacity), low coverage or simply low capacity or data rates networks a user can experiment low QoE and QoS and even the interruption of the service. A traffic offload over a WiFi network (when available) can solve these problems and offer service continuity and improved QoS/ QoE to users and allows load balance between networks.

WiFi offload has emerged as a solution to target the explosion of data traffic in cellular networks due especially to the growth of the video/audio streaming and online games traffic. This data explosion demanding high capacity (and data rates) may cause links to reach the capacity limit so users experiment a low QoE and QoS.

Because of the high increase in mobile users and the high demand in capacity and data rates in the last years, operators have had to reinforce their researches and developments to target this increasing high traffic volume and capacity demand: network optimization (SDN, SON), increase spectrum efficiency, data offloading, etc.

The work in WiFi offloading and load balance is focused in the mobility of traffic flows seamlessly between networks to provide service continuity and mechanisms to the discovery and control of the WiFi networks.

The 3GPP is specifying an approach to the discovery and control of non -3GPP access networks, the Access Network Discovery and Selection Function (ANDSF). The purpose of the ANDSF is to assist users' devices to discover access networks in their vicinity and to provide the policies to access and to prioritize and manage connections to these networks. These policies are operator defined and driven according to their priorities or needs.

Regarding the seamlessly mobility between different networks to offer service continuity during the handover it is necessary to maintain the IP address. The IETF has standardized communications protocols to allow the management and mobility between access networks with IP continuity: PMIPv6 (Proxy Mobile IP v6), a network-based mobility protocol, and MIPv6 (Mobile IP v6), a device user-based mobility protocol.

IV.8.3 : Business value & impact

Delivering video to the TV is no longer enough. Users are demanding the access to multimedia contents from their IP-enabled mobile devices, to watch them anywhere, even on the go. In addition, users will welcome value-added services, such as services to build complex communication environments and enable distributed media applications involving multiple personal and public devices. Service providers should satisfy this demand in order to attract and retain subscribers.

IV.9 End to End Quality

IV.9.1 : Definition

In communication networks, Quality of Service (QoS) applies to the technical characteristics of the lower layers of the OSI model (transport layer and below) from a objective point of view (delay, throughput, etc.) whereas Quality of Experience (QoE) applies to a subjective user's satisfaction with the higher layers of the OSI model including the use of applications that depend on the network.

IV.9.2 : Technical feasibility

As current server capacity and network bandwidth become increasingly overloaded by the rapid growth of high quality emerging multimedia a critical factor of success of these multimedia services becomes the end-user perception of quality while them using the service. As a result, user-centered approaches that consider quality of experience (QoE) constitute the current design trend for network systems of content providers and network operators. The two main challenges are the limited visibility for network operators into home networks performance and its overall status, and the fact that, while QoS is well defined and easy to measure, there is currently no agreed understanding of what constitutes QoE across applications, how to measure it, and how it relates to QoS. Thus, it is necessary to develop new QoE mechanisms to assess the service performance from a user subjective point of view by both developing quality of service (QoS) measurement tools for the home network and subjective models to relate how the quality of experience (QoE) vary with the quality of service (QoS) delivered by the network. The subjetive home user experience measurement makes possible to adapt the contents delivery according to device and network status, to take traffic engineering decisions (SDN) based on content requirements or performance measurements, or to choose the best server in a CDN architecture based on QoE metrics, in order to ensure the customer receives a satisfactory service.

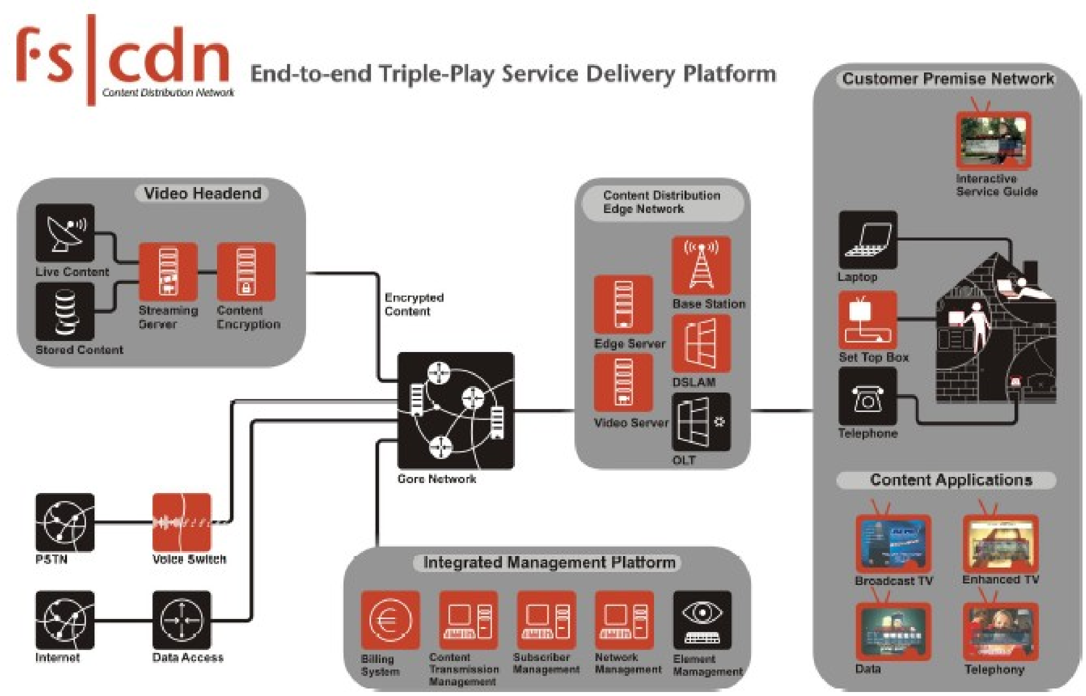
IV.9.3 : Business value & impact

End-to-end monitoring enables service providers to maintain complete visibility of customers' in-home quality of experience (QoE), bringing business value in terms of OPEX and competitiveness improvement. The use of the infrastructure can be optimized from a user centric approach and the issues can be rapidly isolated and resolved. On the other hand, the user satisfaction is increased and new additional revenue streams based on the possibilities of QoE technologies (premium services) are created

VI- Annex

<u>Contemporary state-of-the-art : Intracom's fs|cdn CDN platform</u>

Intracom's fs|cdn™[10] platform is an example of a content delivery network:



It is composed of the following components:

- Video Head-end
- Conditional Access / Content Encryption System
- Content Distribution Edge Network
- Customer Premise Network

They are integrated together through an Integrated Management Platform

The component specifically responsible for the distribution of the content is the edge network. It handles end-user interaction and carries out real-time authentication and authorization of subscribers and delivery of content through the edge servers (cf. fs|cdn™[11] example above). These modules are located either at the Central offices - in the case of a centralized deployment scenario - and/or the Points of Presence (PoPs), in the preferred case of a distributed architecture.

Edge Servers perform user authentication and authorization and instruct the corresponding access node (e.g. DSLAM, OLT) to connect the user with the requested multicast/unicast stream. Edge Servers also transmit the encryption-keys for the requested content and maintain usage records. They also maintain personalized copies of the Interactive Service Guide and retain user preferences, as well as optionally providing value-added services like information / content services on TV.

The distributed Edge architecture employed in the fs|cdn™ platform provides enhanced redundancy, reduces traffic on the core network and allows for service customization and local user

[10] Fs|cdn platform, of Intracom Telecom: http://www.intracom-telecom.com/en/products/telco_software/iptv_multiplay/fs_cdn.htm

[11] Fs|cdn platform, of Intracom Telecom: http://www.intracom-telecom.com/en/products/telco_software/iptv_multiplay/fs_cdn.htm

management. In addition, it allows platform operators to adopt a “buy-as-you-grow” model, minimizing the up-front investment.

For the delivery of Video on Demand (VoD) services, which require point-to-point traffic, two scenarios can be applied depending on the number and the distribution of video subscribers. When subscribers reside in a small concentrated area, they can be served from a single network point of presence (one PoP). In order to serve a larger number of subscribers and avoid single point-of failure, the fs|cdn™ platform can also be deployed in a distributed fashion; replicating the Network Operation Centre (NoC) functionality to distributed PoPs where the VoD and PVR servers are located. Each server handles the requests from a small number of subscribers, reducing the traffic on the core network. A distributed deployment ensures better customer response-times as the servers are near the customer premises, while it allows for gradually serving a larger number of subscribers.

The Customer Premise Network includes all the hardware (DSL modem, Set-Top-Box and/or PC, analogue or IP Phone) and software components (i.e. middleware, applications) that subscribers need to access the available Interactive Content Services.

The video services are implemented using a set of software modules that reside on the customer premise equipment and cooperate with a number of distributed servers located at the Content Distribution Edge Network, enabling service selection, service presentation, application downloading, secure storage, content descrambling and encryption key management.

The fs|cdn™ Client Software comprises Java-based software modules that run on digital TV Set-top-Boxes and PCs, which interoperate transparently with the rest of the fs|cdn™ platform providing a user-friendly interface to service subscribers.

CDN services such as Intracom’s fs|cdn™ platform are designed to support several types of services, ranging from plain telephony to high-speed data access and enhanced video entertainment, which would allow service providers to offer attractive services to their customers and add significant value to their existing customer packages.

Specifically regarding telephony, it must be underlined that such services have been tightly integrated with the fs|cdn™ platform, enabling telecom operators, Internet service providers, property owners, utilities and enterprises to offer true “Triple-Play” Services.

Over the fs|cdn™ platform, users can enjoy advanced telephony and messaging services like Caller-ID, Phone Directory services and messaging over their TV sets. All such services are made available by integrating the fs|cdn™ platform with the existing voice switch or soft-switch that Providers operate.

CDN platforms are normally designed to be application-transparent and accommodate any additional services that may be required by the service providers, or any new applications that may emerge in the future. At any time, the platform can be upgraded in order to enhance the service offerings, according to market and customer demands, enforcing the service provider to obtain market leadership in the multimedia service provision arena.