CONVINcE
D5.2.1

Measurement tools development completion and calibration, integration into test-bed(s)

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1   EXECUTIVE SUMMARY

The Objective of this report ("D.5.2.1") is to describe the tools used for the power consumption measurements in different use-case scenarios defined under the scope of CONVINcE. This document also describes the how these scenarios forms the end to end integrated demonstration.

Three different use-case scenarios defined under the scope of CONVINcE are:

- On Demand Video Streaming
- Live Video Streaming
- Camera-based Sensor Networks.

The project end-to-end demonstration result verification is done using these three scenarios.

Deliverable D5.2.1 falls under work package WP5 where evaluation and conclusion of the end to end delivery chain WP5 chain i.e. integrated demonstration is done.

Use-case scenarios definition and identification of power saving mechanisms from head end, network to terminals are done within work packages WP2, WP3 and WP5. These work packages contains different main components which combines to form end-to-end video delivery chain.

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2   DOCUMENT HISTORY AND ABBREVIATIONS

2.1 Document history

Version	Date	Description of the modifications
1.0	28.11.2016	Defined Table of Contents
1.1	23.12.2016	Approved Table of Contents and content update from partners.
1.2	11.1.2017	Added Partners contribution
1.3	25.1.2017	Added all Partners contribution
1.4	9.2.2017	Added all Partners modifications based on review comments
1.5	1.3.2017	review comments incorporated and Final cosmetic modification completed

2.2 Abbreviations

AAA	Authentication Authorization Accounting
CMTS	Cable Modem Termination System
CNOM	Cognitive Network Operation and Management
CSV	Comma Separated Value
DTTV	Digital Terrestrial Television
HDMI	High Definition Multimedia Interface
HD	High Definition
HEVC	High Efficiency Video Coding
IP	Internet Protocol
OF	OpenFlow
PMT	Power Measurement Terminal
QIP	QAM Internet Protocol
QoE	Quality of Experience
QoS	Quality of Service
SD	Standard Definitions
SDN	Software Defined Networking
STB	Set Top Box
UI	User Interface
VoD	Video on Demand

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3 INTRODUCTION

The overview of the demonstrator scenario.
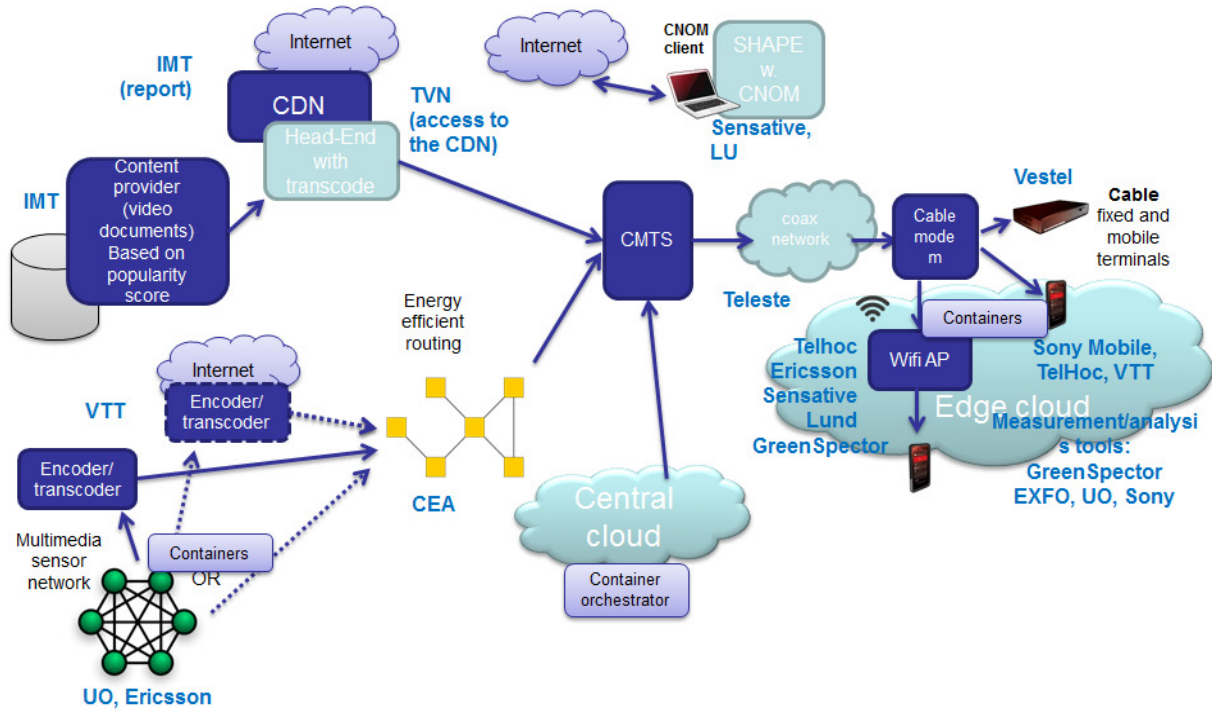
The Integrated Demonstrator Scenario

Figure 1: Integrated Demonstrator Scenario

The Demonstrators - Synoptic Diagram
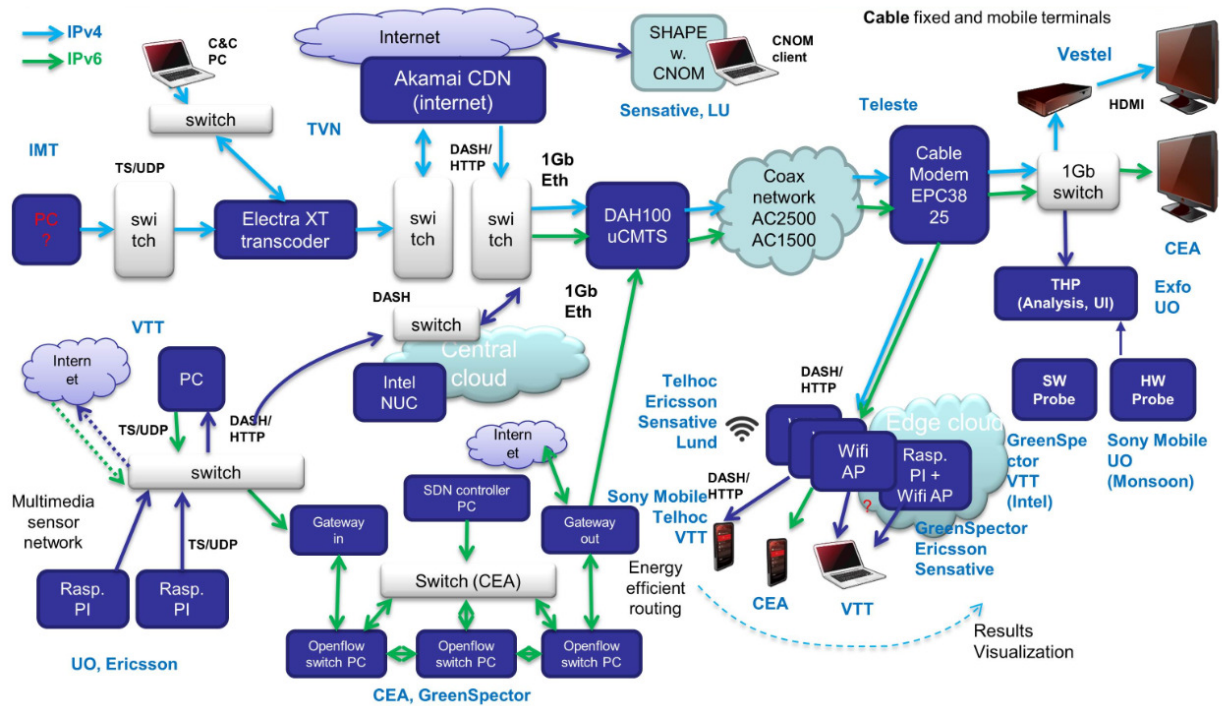
Figure 2: Demonstrators - Synoptic Diagram

4 DEMONSTRATOR MEASUREMENT TOOLS

This section describes the different Tools used for the power consumption measurements in different use-case scenarios defined under the scope of CONVINcE.

4.1 Source and Head End

4.1.1 Video Surveillance Network

Partners: **University of Oulu, Ericsson and VTT**
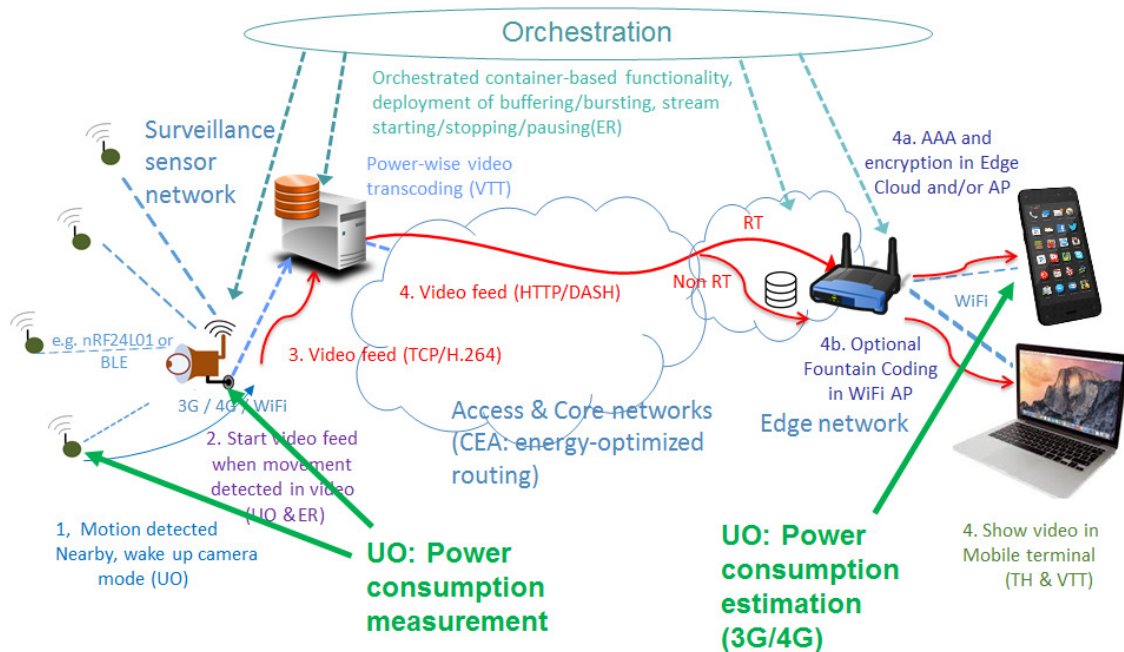
Figure 3: Video Surveillance Network

4.1.1.1 Description

Motion detectors: the motion detectors are Waspmotes that can be measured e.g. using a Monsoon or Sony power measurement tool. The Waspmotes wake up the video sensors using a Bluetooth signal.

Video sensors: the video sensor consists of a Waspmote connected via an electrical relay to a Raspberry Pi. The set up can be measured with the same tools as motion sensors. The Raspberry Pi can be measured also using USB-1608FS-Plus tool.

Video transcoding server: the video transcoder is a powerful desktop PC that is connected to wall power socket. Power consumption is currently measured using Eaton power board, but can be also measured using e.g. BTH power measurement tool.

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Orchestrator: The orchestrator is a Raspberry Pi running docker swarm that can be measured using USB-1608FS-Plus. Alternatively, GreenSpector's measurement tools could be also used.

University of Oulu will use Monsoon or Sony QiP power monitors to measure the power consumption of the sensor nodes (camera sensor node, activity detection sensor node) in the Surveillance scenario demo.

4.1.1.2 Calibration

The absolute output values from the measurement devices can be calibrated and be compared with output results from other available power consumption measurement systems available on the market. The measurement device clocks need to be calibrated for each measurement point, in order to accurately visualize the system-wide power consumption in EXFO UI.

Multiple alternative tools exist for conducting the measurements. The precision of the different tools can be verified by comparing them to the others.

4.1.2 Video Sources and Software Encoder

Partner: **VTT**

4.1.2.1 Description

The video encoder/transcoder is a powerful desktop PC that is connected to wall power socket. Power consumption is currently measured using Eaton power board, but can be also measured using e.g. BTH power measurement tool.

4.1.2.2 Calibration

The output values from the encoder/transcoder can be created enabling/disabling power-wise software encoding options and comparing these values with each other. Comparison between different codecs such as H.264 and HEVC will be also made.

The measurement device clock needs to be synchronized with the encoder/transcoder in order to visualize the results with EXFO UI.

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4.1.3 Popularity Chosen Video Streams

Partner: **IMT**

Popularity Chosen Video Streams is a module which uses popularity metrics and factors to compute the popularity of videos. It gets the videos meta-data as a CSV file and gives them a priority number representing their popularity. This module helps to decide which videos should be cached in the networks which leads to decrease the data traffic and consumed energy in the network consequently.

4.1.3.1 Description

Popularity is measured by different metrics depending on its application. The most important factors considered in video popularity measurements are the number of views, and number of likes. The publish date also is an important item to compare the videos popularity numbers. In this module we compute the popularity of videos as follows:

$$\boldsymbol{without\ Date_{publish}}:\ Popularity = \alpha(\#views_{total}) + \beta(\#likes_{total}) + \gamma\left(\frac{\#likes_{total}}{\#views_{total}}\right)$$

$$\boldsymbol{with\ Date_{publish}}:\ Popularity = \alpha\left(likes_{daily}\right) + \beta\left(views_{daily}\right) + \gamma\left(\frac{likes_{daily}}{views_{daily}}\right)$$

$$likes_{daily} = \frac{\#likes_{total}}{\#days}\ ,\ views_{daily} = \frac{\#views_{total}}{\#days}$$

The value of coefficients are varying based on available meta-data of videos. The module is implemented with Python. Meta-data file of videos is the input and the ranked list of videos regarding the computed popularity value is the output

4.1.3.2 Calibration

No calibration is required.

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4.1.4 Transcoding

Partner: **Harmonic**

4.1.4.1 Description

A cost-effective appliance for live content transcoding, the Electra XT provides high-density and scalability for traditional broadcast over cable, IPTV, DTH and DTTV, as well as for multiscreen applications.

The Electra XT receives compressed video over IP streams and can transcode audio and video content from any format to any other format.

For video, the device supports MPEG-2 and MPEG-4 AVC in SD and HD resolutions. A wide range of audio codecs is also addressed, including MPEG-1 Layer II, Dolby® Digital (AC-3), Dolby Digital Plus (E-AC-3), AAC-LC and HE-AAC v1/v2 in mono, stereo and surround modes.

Leveraging extensive experience and innovation in video compression algorithms, the Electra XT provides best-in-class transcoding density with up to 180 SD or 54 HD channels in 2 RU. It is designed with efficiency in mind, and supports operator business growth with a modular architecture that accommodates up to nine hot-swappable audio/video processing modules. Each module supports 20 SD or six HD channels (or a mix) through per-channel software licensing.

The high-density benefits of the transcoder significantly reduce rack space and **minimize power consumption**. A flexible web-based graphical user interface facilitates the configuration and supervision of hundreds of simultaneous transcode channels.

Error! Reference source not found. shows Electra XT in a typical headend and

Table 1 gives its specification.

Figure 4: Electra XT in a typical headend
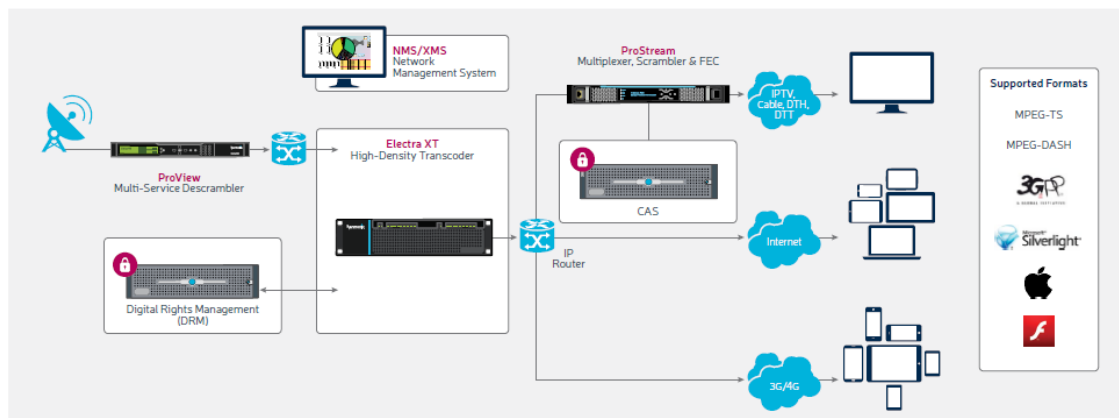
VIDEO INPUT/OUTPUT	AUDIO PROCESSING

Live Inputs
    • MPEG-2 TS over IP (RTP or UDP)
    • Unicast and multicast
    • IGMP v2 and v3
    • MPTS and SPTS
    • CBR and VBR
	Features
	    • Any-to-any audio transcoding
	    • Stereo and multichannel support
	    • Audio pass through support
	Encoding Profiles
	    • MPEG-1 Layer II

Broadcast Live Outputs
    •   MPEG-2 TS over IP (RTP or UDP)
    •   Unicast and multicast
    •   MPTS and SPTS
    •   CBR and VBR
    •   Internal statistical multiplexing
Multiscreen Live Outputs
    •   ABR encoding support
    •   MPEG-2 TS over IP (with EBP)
    •   Adobe RTMP
    •   Apple HLS
    •   Microsoft Smooth Streaming
    •   MPEG-DASH
Physical Interface
    •   Integrated redundant IP switch with:
    •   1+1 GigE ports for supervision
    •   2+2 10GigE optical ports for media
    •   4+4 GigE ports for media
	• AAC-LC/HE-AAC v1/v2
	    • AC-3
	    • E-AC-3
	Decoding Profiles
	    • MPEG-1 Layer II
	    • AAC-LC/HE-AAC v1/v2
	    • AC-3
	    • E-AC-3
	Automatic Loudness Control
	    • EBU R128
	    • A-weighting
	Processing Capabilities
	    • Resampling (8-48 kHz)
	    • Stereo/mono conversion
	    • Surround down-mixing
	    • Static gain adjustment
	    • Delay adjustment

VIDEO PROCESSING
Features
    •   Any-to-any video transcoding
    •   Up to 54 HD or 180 SD channels
Encoding Profiles
    •   MPEG-2
        o   MP @ ML
        o   MP @ HL
    •   MPEG-4 AVC
        o   BP @ L3
        o   MP @ L3
        o   HP @ L4
Decoding Profiles
    •   MPEG-2
        o   MP @ ML
        o   MP @ HL
    •   MPEG-4 AVC
        o   MP @ L3
        o   HP @ L4
Resolutions and Frame Rates
    •   Up to 1920x1080i @ 30 fps
    •   Up to 1280x720p @ 60 fps
    •   Minimum Resolution
        o   64x64 pixels
    •   Resolution Adjustment Steps
        o   2x2 pixels
    •   Frame Rate Adjustment
        o   5-60 fps
    •   Processing Capabilities
        o   Picture resizing (up/down)
        o   Picture cropping/clipping
        o   Aspect ratio conversion
        o   Smart deinterlacing
        o   Logo overlays
        o   Crawling text overlays
    •   Broadcast Subtitles
        o   DVB subtitle passthrough and burn-in
        o   Teletext passthrough
        o   Closed-caption passthrough
    •   Multiscreen Subtitles
        o   WebVTT
        o   DFXP
        o   SMPTE-TT
    •   Ad Insertion SCTE
        o   35 passthrough
        o   ESAM compliant
    •   Multiscreen Content Protection
        o   AES scrambling
        o   Apple HLS encryption
        o   Microsoft PlayReady® DRM
	PHYSICAL
	Dimensions
	    • (H x W x D) 3.5 in x 19 in x 22.8 in (2 RU)
	    • 8.8 cm x 48.3 cm x 58 cm
	Weight
	    • 46.2 lbs/21 kg
	Hot-Swappable Components
	    • Dual AC power supplies
	    • Fans
	    • A/V processing modules
	    • IP switches
	ENVIRONMENTAL
	Operating Temperature
	    • 23° to 131° F
	    • -5° to 55° C
	Relative Operating Humidity
	    • 5-93% non-condensing
	Storage Temperature
	    • -40° to 185° F
	    • -40° to 85° C
	Relative Storage Humidity
	    • 5-93% non-condensing

Table 1: Electra XT specifications

4.1.4.2 Calibration

No calibration is required for Electra XT.

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4.1.5 Shape w.CNOM

Partner: **Sensative**

4.1.5.1 Description

4.1.5.1.1 Test set-up
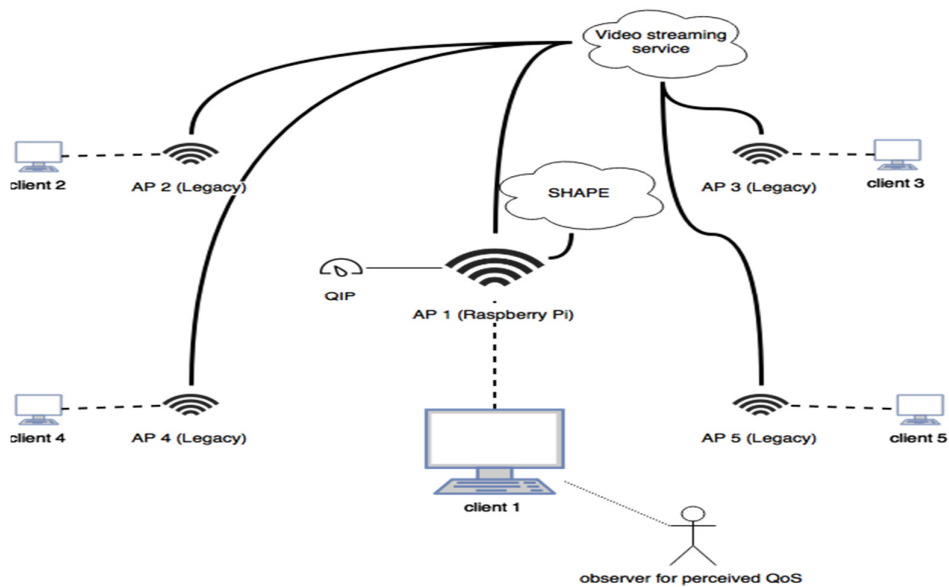
Figure 5: Test Set –up

4.1.5.1.2 Devices

Required devices are:

- 5 access points
    - 1 of them should be a Raspberry Pi running OpenWrt
- 5 computers receiving mobile devices connected able to connect to the access points
- QIP for measuring power consumption on AP 1

4.1.5.1.3 Set-up

- All APs should be operating on the same channel, e.g. channel, on the 2,4 GHz band.
- AP 1 should be in reach for the other APs (2-5).
- AP 1 should have the power consumption measurement tool, the QIP, connected to it.
- AP1 should have a separate script running for collecting the actual QoS data
- client 1 should have an observer collecting data of the perceived QoS of the video

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4.1.5.1.4 Execution

The test will consist of three phases, firstly only AP 1 (using default settings) and client 1 should be running. Then all APs (with default settings) with connected clients should be running. And finally all APs with connected clients should be running, and AP 1 should be connected to SHAPE with the Cognitive Network Operation and Management (CNOM).

During each phase all clients should consume a 10 minutes long video from a video streaming service chosen based on popularity, e.g. YouTube. Each test phase is done when the video has finished on client 1, and it should therefore take at least 10 minutes.

In between every test phase all clients should reload the video streaming page and clear their cache.

4.1.5.1.5 Measured values

Only AP 1 and client 1 will be measured. The measurements will be done during each of the test phases.

- AP 1
    - power consumption in Watt
    - actual QoS, the ratio of lost to transmitted packets over the WiFi in percentage & data throughput
- client 1
    - power consumption in Watt
    - perceived QoS, the time where the observer is waiting for the video to play (buffering) in seconds

4.1.5.1.6 Factors for success

The CNOM can be proven useful if either of the following results are found comparing phase 2 and 3:

- the power consumption on the AP is lower
- the actual QoS is lower
- the perceived QoS is higher

Phase 1 test result will be used as the theoretical target for phase 3

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4.2 Network

4.2.1 Energy Efficient Routing

Partners: **CEA and GreenSpector**

4.2.1.1 Description

The goal of the demonstration is to show that an energy-aware routing approach can reduce the overall energy consumption in networks. The testbed is composed of an SDN controller and three openflow (OF) switches. The SDN controller consists in 1 PC using UBUNTU 14.04 system where we install the NEON controller software. Each OF switch consists in 1 PC using UBUNTU 14.04 system where openvswitch and NEONd softwares are installed.

We will use Greenspector probe to measure power consumption (the instantaneous power consumption of the PC or just related to openvswitch software) in each OF switch. The measurement process is shown in Figure 6. The observation points will send their measures to Greenspector server where they will be processed and showed after in Greenspector webpage.
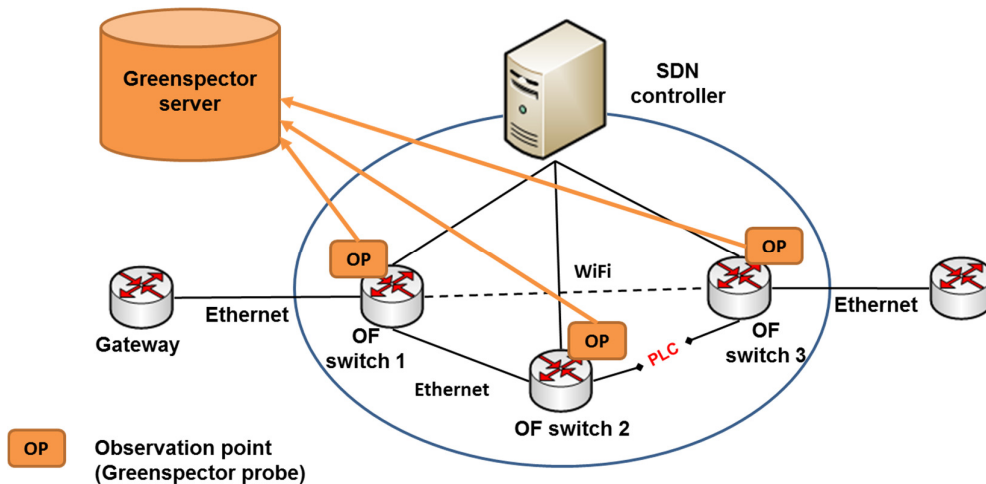

Figure 6: measurement process in CEA testbed

4.2.1.2 Calibration

Greenspector probe is based on the use of powerAPI software that need no calibration.

4.2.2 CDN

Partner: **IMT**

CDN evaluation is a module to measure the consumed energy in CDNs

4.2.2.1 Description

CDN evaluation module considers the CDN's energy consumption methods available in the literatures to compute the consumed energy in a CDN. Different methods are proposed in the literatures with considering variety number of parameters. We compared the different methods and chose the most complete ones to use in this module. Two following equations are chosen to compute the CDN's consumed energy:

$$E_{tot}{}^{CDN} = E_{tr}{}^{c} + E_{tr}{}^{e} + E_{st} + E_{sr}$$

Where $E_{tr}{}^{c}$, $E_{tr}{}^{e}$, E_{st}, E_{sr} are the amount of energy consumed in core, edge, storage, server respectively.

$$E_{tot} = E_{storage} + E_{server} + E_{synch} + E_{tx}$$

More details about the computing each part are available in CDN evaluation report.

4.2.2.2 Calibration

No calibration is required.

4.2.3 Cable Network

Partner**: Teleste**

4.2.3.1 Description
Power efficiency figures for node and amplifiers are achieved through a combination of performance verification measurements and capacity calculation. Performance measurements that validate the maximum throughput capacity have been performed separately and no power measurement will take place at the review.

4.2.3.2 Calibration

No calibration required.

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4.2.4 Edge Cloud

Partners: **Greenspector and Ericsson**

4.2.4.1 Description

Ericsson will use Raspberry Pis (running Docker) as Edge Cloud nodes (e.g., Wi-Fi Access Points running video stream optimization software), and thus some of the same measurement tools mentioned above (e.g.) in subsection 4.1.1 (such as USB-1608FS-Plus) can be used.

Greenspector will provide its server probe to measure energy consumption on the edge cloud. It consists in a software probe using PowerAPI as a backend to measure the energy consumed by CPUs.

4.2.4.2 Calibration

The only requirement to calibrate the Greenspector server probe is the TDP value of the CPUs to be measured.

4.2.4.3

4.2.5 WIFI Access Points

Partner: **TelHoc**

TelHoc will utilize a WiFi Access Point that relies on YoctoWatt for collecting power consumption measurements.

4.2.5.1 Description

The TelHoc WiFi AP will include a YoctoWatt chip that will be able to continuously collect power measurements values in a programmable way. This means that terminals will be able to collect these values and combine them with their own measurements for a combined power consumption value of both the AP and the terminal and report these values for post analysis AND real time display (GUI).

4.2.5.2 Calibration

Calibration will be conducted pre deployment based on USB Watt probes driving the power of the AP.

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4.3 Terminals

4.3.1 Fixed Terminals

Partner: **Vestel**

Power measurement of fixed terminals will be done separately from the rest of the demonstrator. There will be two fixed terminals which will be used in the use cases, Video on Demand and Live Video which are STB and Display Unit.

4.3.1.1 Description

Power measurement models of STB and Display Unit will be covered on this demonstration. In our power measurement model of STB, Active Mode processing power of main IC will be calculated first, and then power spent by HEVC and AVC video decoding will be measured. On Display Unit side, during video playback, power consumption of it will be calculated.

All these setups will be demonstrated for both non-power optimized device and power optimized device. Wattmeter will be used for power measurements of STB and Display unit setups. To be demonstrated setups are described below tables.

Setup	Set Top Box Properties	Display Unit Properties	Video Properties	Setup Content
•Setup 1			- 1280x720p - I-period 48, GOP 8 - 4.2 Mbps - 50fps - AVC-avg-PSNR 40.9 dB • - HEVC-avg-PSNR 43.3 dB	• - Video codec: H264 • - Device: Set Top Box • - Comparison of power consumption between Active Mode and during video decoding
•Setup 2	• - AVC / HEVC • - DVBS2 • - Ethernet	• - 39' FHD • - Wifi • - AVC / HEVC		• - Video codec: H265 • - Device: Set Top Box • - Comparison of power consumption between Active Mode and during video decoding
•Setup 3				• - Video codec: H264 • - Device: Display unit • - Comparison of power consumption between Active Mode and during video playback
•Setup 4				• - Video codec: H265 • - Device: Display unit • - Comparison of power consumption between Active Mode and during video playback

Table 2: Power measurement setup without power optimization

Setup	Convince Set Top Box Properties	Convince Display Unit Properties	Video Properties	Setup Content
Setup 1			- 1280x720p - I-period 48, GOP 8 - 4.2 Mbps - 50fps - AVC-avg-PSNR 40.9 dB	• - Video codec: H264 • - Device: Convince Set Top Box • - Comparison of power consumption between Active Mode and during video decoding
•Setup 2	• - AVC / HEVC • - DVBS2 • - Ethernet	• - 39' FHD • - Wifi • - AVC / HEVC		• - Video codec: H265 • - Device: Convince Set Top Box • - Comparison of power consumption between Active Mode and during video decoding
•Setup 3			- HEVC-avg-PSNR 43.3 dB	• - Video codec: H264 • - Device: Convince Display unit • - Comparison of power consumption between

				Active Mode and during video playback
•Setup 4				• - Video codec: H265 • - Device: Convince Display unit • - Comparison of power consumption between Active Mode and during video playback

Table 3: Power measurement setup with power optimized devices

The demonstration setup of power measurement of STB's and Display unit's will be constructed as seen figure below. HEVC and AVC coded videos will be included on server and usb flash. Since measure the power consumption of Set Top Box during video decoding, STB will be connected to PMT. At the same time, the Display Unit will also be connected to PMT to gather measurement data. Measured average and instant power consumption values are transmitted from PMT to PC to evaluate them.
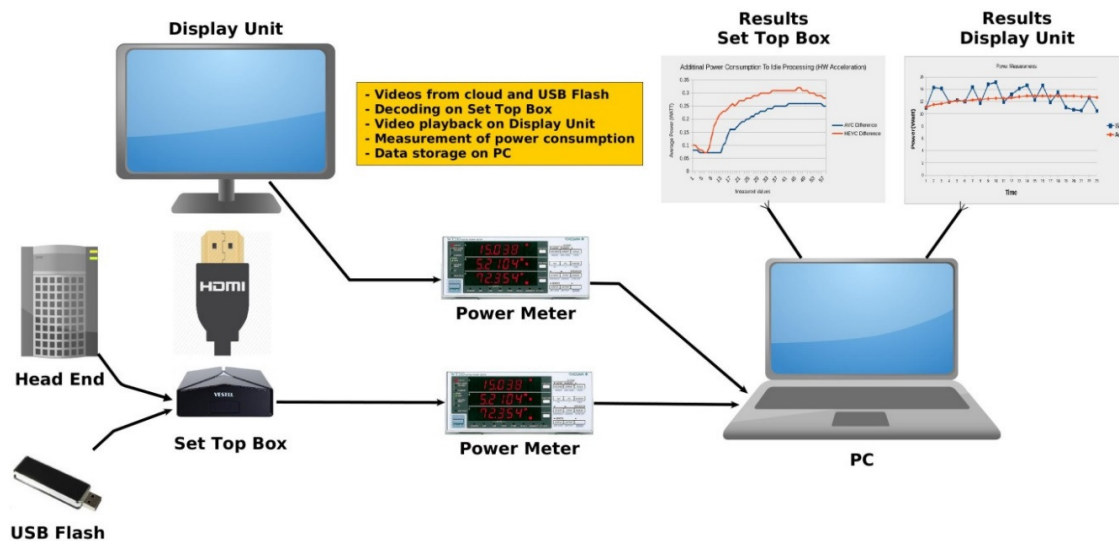
Figure 7: Fixed terminal power measurement setup

4.3.1.1.1 Inputs

Video playback measurements will be made by using AVC and HEVC encoded videos have properties as below.

- *1280x720p*
- *I-period 48, GOP 8*
- *4.2 Mbps*
- *50fps*
- *AVC-avg-PSNR 40.9 dB*
- *HEVC-avg-PSNR 43.3 dB*

4.3.1.1.2 Outputs

Average and instant power consumption values are received from PMT by PC over serial interface. Output values from the power meter tool towards to PC are instant voltage, instant current, instant power consumption, and average power consumption. A script file has been coded to do two important things. One is receiving data from PMT to PC over serial interface and the other is passing all received data into excel file.

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4.3.1.2 Calibration

No calibration is required.

4.3.2 Mobile Terminals

Partners: **Sony Mobile, Telhoc, GreenSpector, EXFO, UO, VTT**

TelHoc will use Android Nexus 5 which includes a Maxim MAX17050 HW modules that reports power drainage via battery. TelHocs demo application collects these values for logging and live reporting in the GUI.

To study practical power reduction achievable in current machines, **VTT** will use Apple MacBook Pro 15″ and Apple MacBook Air 13″ laptop computers and optionally Apple iPhone 6 Plus and Apple iPhone 7 Plus smartphones and Apple iPad Air 2 tablet computer as mobile terminals. In the tests, the terminals will receive video streams, decode them and playing back them on the screen as well as measurement software for determining the power consumption of the processor (to reflect the power consumption of video processing) or the whole machine.

4.3.2.1 Description

A measurement tool for quantifying the power consumption of the mobile devices used in the CONVINcE test bed is being developed by **Sony Mobile** within the CONVINcE project. This measurement tool can here be denoted the „Sony Mobile measurement system". The Sony Mobile measurement system consists of a hardware measurement box combined with a computer software tool.

The Sony Mobile measurement system can be used to produce energy consumption measurement results, in terms of both visual graphs as well as statistics collection. The statistics can be produced and stored as xls files for further analytics.

University of Oulu will provide an estimation tool for estimating the power consumption of 3G and 4G networks based on the terminal traffic profile of the scenario, in addition to the power consumption measurement values for WiFi-connected mobile terminal.

EXFO will be using TravelHawk Pro device for capturing and analysing network traffic for devices under test i.e. Android smartphone with different communication channels providing video data: 4G, 3G core networks.

http://www.exfo.com/products/field-network-testing/bu1-mobile-broadband/network-analysis-monitoring/travelhawk-pro

VTT will use Intel Power Gadget, Apple Instruments and FIPLAB Batter Health measurement software.

- **Intel Power Gadget.** *It* is a software-based power usage monitoring tool enabled for 2nd Generation Intel Core processors or later. It is supported on Windows and Mac OS X and includes an application, driver, and libraries to monitor and estimate real-time processor package power information in watts for both the processor cores (so called IA measurement) and the whole processor chip (including on-chip GPU) using the energy counters in the processor. We used version 3.0.3 for Mac OS X. The frequency of measurements in 1-1000 Hz (default 10 Hz) and resolution 0.005W in Intel processors supporting it.

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- **Apple Instruments.** This is a performance-analysis and testing tool for dynamically tracing and profiling Apple OS X and Apple iOS code. It is provided as a part of Apple XCode 3.0 or newer development SW package. With Apple Instruments it is possible to

    - Examine the behavior of one or more processes

    - Record a sequence of OS X user actions and replay them, reliably reproducing those events and collecting data over multiple runs

    - Profile apps in OS X and in iOS (in iPhone or iPad Simulator, or on a physical iOS device)

    - Create custom DTrace instruments to analyze aspects of system and app behavior

    - Save user interface recordings and instrument configurations as templates

    - The frequency of measurements in 1 Hz and resolution 0.085W in iPhone 6 Plus and 0.25W in iPad Air 2.

We used version 8.2.1 along with Apple XCode 8.2.1

FIPLAB Battery Health. *It* is a tool for gaining vital information about Apple MacBook's battery, such as current charge level, battery capacity, power usage, temperature, charge cycles. We used version 5.4 for Mac OS X.

Greenspector will provide its Android probe to perform measurements on the Android based mobile terminals. This probe collects data about the energy consumed, the CPU and network activity and the memory load of the devices.

4.3.2.2 Calibration

The absolute output values from the **Sony Mobile** and Monsoon measurement systems can be calibrated and be compared with output results from other available power consumption measurement systems available on the market.

EXFO TravelHawk Pro is a passive network monitoring tool that do not contain any components requiring calibration.

For calibration and accuracy purposes, **VTT** will compare the Apple Instruments and FIPLAB Battery Health results with practical power measurement done by fully charging the battery of the terminal, running a video workload for a long time so that e.g. 70% of the battery is used, and comparing the used energy (70% of the battery capacity) to that shown by the software. We will periodically calibrate the battery power measurement with the following procedure:

a) Fully charge the terminal battery.

b) Once fully charged, leave it plugged in for at least another 2 hours.

c) Remove the power adapter, and use the terminal until the battery level warning message is shown.

d) Ignore that message and keep running your notebook.

e) Eventually the machine will go to sleep.

f) Let it sleep for at least 5 hours.

g) After the time has passed, plug it back in, and let it fully charge.

h) Once fully charged, the battery has been properly calibrated.

Greenspector Android probe may require calibration depending on whether the devices are already supported or not. If the devices are supported, the probe will work out of the box. If not, a calibration will be performed to specify the location of the system data that will be monitored by the probe.

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5 INTEGRATION INTO END TO END TEST-BED

This section describes how different measurement tools and use-case scenario are integrated to form one end to end integrated demonstration scenario show in the figure below.
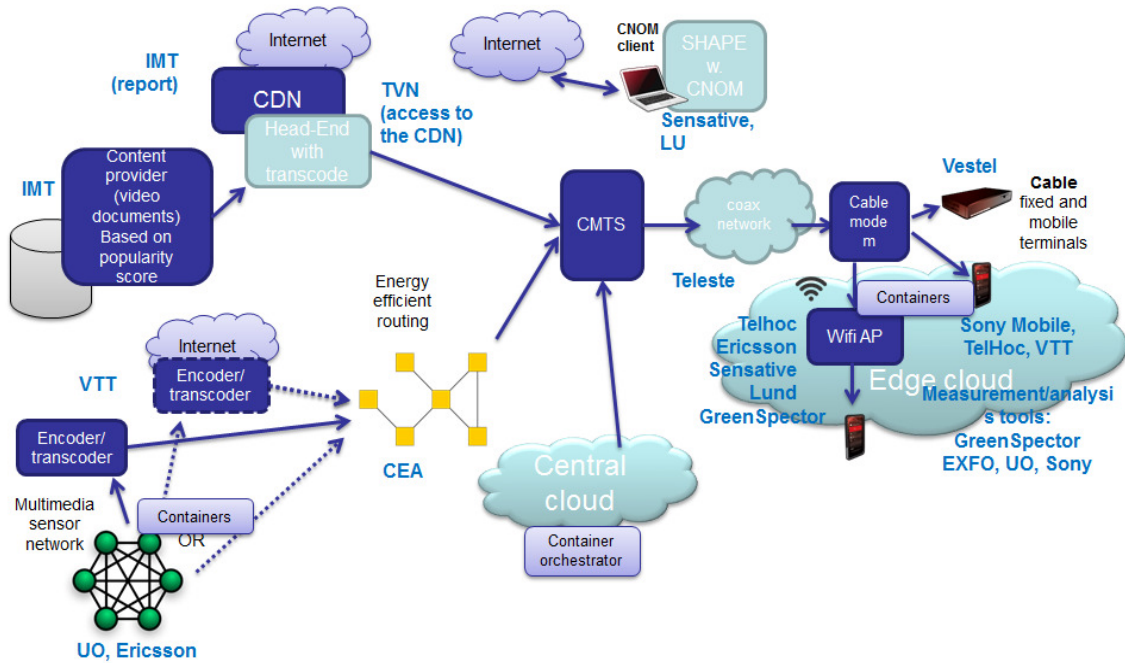
The Integrated Demonstrator Scenario

Figure 8: Integrated Demonstrator Scenario

5.1 Source and Head End

5.1.1 Video Surveillance Network

Partners: **University of Oulu, Ericsson, VTT**
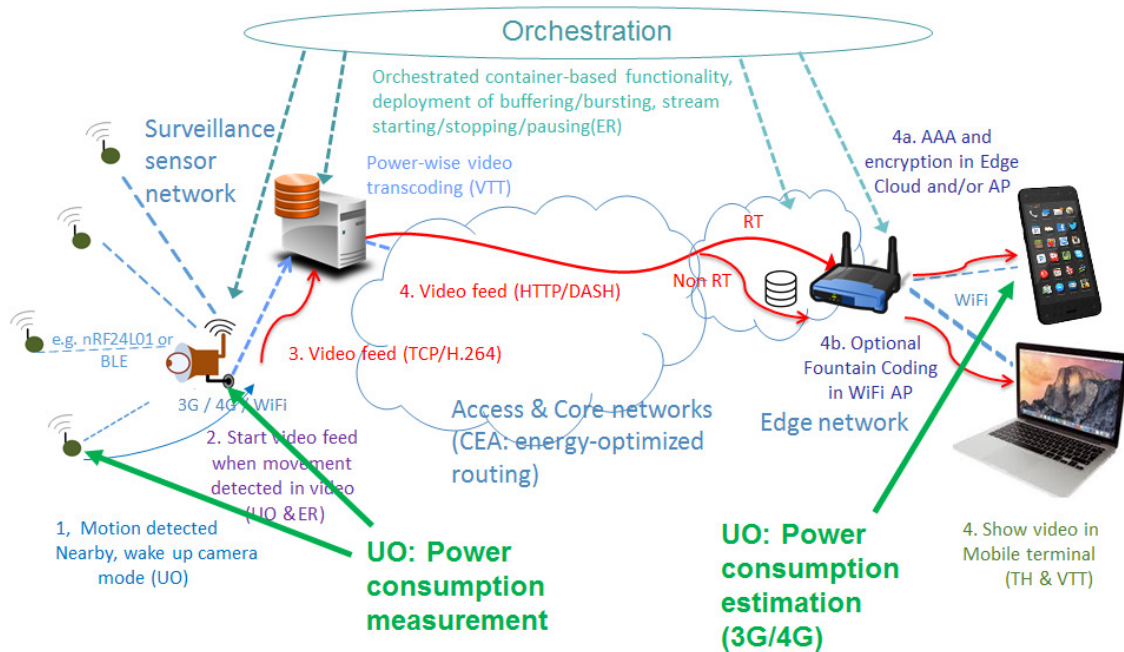
Figure 9: Video Surveillance Network

5.1.1.1 Integration Process Description

The consumption data from Monsoon and Sony measurement system will be exported as comma-separated value (CSV) and displayed with the power consumption of other systems components using the EXFO UI.

5.1.1.2 Parameters to be measured

The measured parameters of mobile terminal energy consumption is the instantaneous and average power consumption in Watt. The values change between a few mill watts and a few watts.

Motion sensors: The measured value for motion sensors is power consumption in watts.

Video sensors: The measured value for video sensors is power consumption in watts. Docker may introduce max 1 watt extra power draw in Raspberry

Video transcoding server: The measured value for video transcoding server is power consumption watts. In addition CPU load is visualized.

Orchestrator: The orchestrator is a Raspberry Pi. Version 3 consumes 1.4 (idle) − 3.7 (400 % CPU load). It is expected that the energy consumption of the orchestrator is closer to the lower end because orchestration is not a heavy duty task (with only occasional peak loads).

Access point: Instantaneous and average power values in mW. Optionally energy in J.

Terminals: Instantaneous and average power values in mW. Optionally energy in J. As reported by Android HW modules in Nexus 5.

5.1.2 Video Sources and Software Encoder

Partner: **VTT**

5.1.2.1 Integration Process Description
The VTT encoder provides either VoD or live MPEG-DASH content and is the source point of the video transmission path. Live content can be real-time encoding from

   a) File: input content is raw yuv.

   b) camera: input content is encoded/raw content from webcam/phone

   c) Surveillance feed from UO: input content is h264-encoded stream from network.

The software encoder power consumption is displayed real-time from the visualization laptop and also exported as CSV file to be visualized by EXFO UI.

5.1.2.2 Parameters to be measured

The software encoder power consumption is measured in watts concerning the total consumption of the encoding server. Idle consumption will be also measured. CPU usage as a percent value can be also visualized. Consumption between different codecs will be measured. Novel codecs will consume slightly more power for achieving same video quality, but require less bandwidth in the transmission.

5.1.3 Popularity Chosen Video Module

Partner: **IMT**

Popularity chosen video module calculates the popularity metric of videos and provides ranks to the videos, which indicates the priority of videos for caching or streaming in the network. The module sorts the videos based on their popularity before the streaming phase to TVN's Akamai account. The functionality of this module is independent to the streaming part of the network as well as the coding of the videos, and only works with metadata of videos.

5.1.3.1 Integration Process Description

Based on the functionality of this module, there is no integration to the system and it works as an independent module and only the output of this module will be used in the scenarios

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that there are several videos. In this case, for the order of streaming, the input of this module will be used that provide a list of sorted videos.

5.1.3.2 Parameters to be measured

The module computes the popularity of videos using the input parameters such as number of likes and views. There won't be any independent measurement in this module in the demo. But the performance of this module will be measured separately to ensure that the sorted videos are the right one. The evaluation will show that in compare to the random selection of videos, using popularity module will enhance the traffic and cashing strategy of the whole system.

5.1.4 Transcoding

Partner: **Harmonic**

5.1.4.1 Integration Process Description
Consumption of Electra XT transcoder will be measured with Open Energy Monitor in different configurations, including full load of the transcoder.

5.1.4.2 Parameters to be measured

Average and instantaneous power consumption will be monitored.

5.1.5 Shape w.CNOM

Partner: **Sensative**

5.1.5.1 Integration Process Description
This is described in detail in Section 4.1.5.1.1

5.1.5.2 Parameters to be measured

This is described in detail in Section 4.1.5.1.5

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5.2 Network

5.2.1 Energy Efficient Routing

Partner: **CEA**

5.2.1.1 Integration Process Description
As a first step, we will integrate Greenspector probes in the energy-efficient routing testbed. After that, we will perform some tests with these probes and analyze the obtained results.

As the partners that are going to use our testbed will generate MPEG-DASH traffic, the second step of integration will consist in testing our testbed with MPEG-DASH traffic and check if it causes any issues. In addition, we will need the IP addressing plan from the partner Orange Labs that will be used in the final demo in order to configure our testbed accordingly.

The third step of integration process, we will meet the rest of partner in 3/03/2017. For this meeting we will transfer our testbed to Orange Labs building and integrate it in the final demo. Some tests need to be done in order to check if there are issues and resolve them.

5.2.1.2 Parameters to be measured
The instantaneous and average power consumption of the PC or just related to the openvswitch software.

5.2.2 CDN

Partner: **IMT**

CDN evaluation is a module to survey the methods to compute a CDN's consumed energy available in the literatures. As there is not access to the CDN network in the project, this module get the network information like number of hubs, number of servers, number of documents, size of documents, cache size and so on, and measures the amount of energy consumed in the CDN network.

5.2.2.1 Integration Process Description

This module can be considered to be integrated in the CDN part of the network to evaluate the CDN consumed energy based on the literature studies.

5.2.2.2 Parameters to be measured

It computes the amount of energy consumed in CDN which is used in integration process.

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5.2.3 Edge Cloud

Partners: **Greenspector and Ericsson**

5.2.3.1 Integration Process Description
Edge Cloud nodes that are Raspberry Pis can be measured (and the values exported accordingly) as described in subsection 5.1.1 if needed.

The Greenspector server probe will be installed on the servers to be measured. This installation consists in installing a Java environment (version 7 or higher) and PowerAPI, besides installing the probe itself. Its collected data will be converted to CSV format to be visualized in EXFO UI.

5.2.3.2 Parameters to be measured

CPU consumption will be measured Greenspector server probe.

5.2.4 Cable Network

Partner: **Teleste**

5.2.4.1 Integration Process Description
Cable network part of the demonstrator will be installed in Orange premises, configured and powered up for other partners to use in their demonstrations.

5.2.4.2 Parameters to be measured

No measurement of cable network takes place in the review

5.2.5 WIFI Access Points

Partner: **Telhoc**

TelHoc will measure power via a YoctoWatt chip as well as via estimation methods as provided by BTH. This will include real time measurements as well post analysis values provided to the EXFO tool. In addition these measurement point will be integrated into TelHoc software.

5.2.5.1 Integration Process Description

TelHoc has an API for collecting power consumption measurements in real time and for post analysis from the connected/embedded (based on used version of the TelHoc AP) YactoWatt module. These values will also be provided to terminals via TelHoc's REST API, if terminals so desires.

5.2.5.2 Parameters to be measured

Power (W) per time, real-time and Theoretical/SOTA values (if considered and provided by BTH).

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5.3 Terminals

5.3.1 Fixed Terminals

Partner: **Vestel**

The fixed terminals are STB and TV display. The green software development will be demonstrated on STB and the improvements on power efficiency at the display unit will be demonstrated at TV.

5.3.1.1 Integration Process Description

The STB will be connected to TV via HDMI. There will be VOD application running on the STB and TV unit will be used as a display unit.

The integration process will include these steps:

• Integration of STB with cable modem

• Integration of STB VOD application with transcoder at the head-end

• Power measurement of STB and TV tool integration

• IpV6 network setup integration with STB

5.3.1.2 Parameters to be measured

Total power consumption of STB and TV will be measured.

5.3.2 Mobile Terminals

Partners: **Sony Mobile, Telhoc, VTT, EXFO, UO, Greenspector**

5.3.2.1 Integration Process Description

The **Sony Mobile** measurement system and Monsoon Power Monitor will be integrated into the CONVINcE test bed by means of connecting hardware power cables from the measurement system box to the battery connectors of the mobile terminal.

EXFO TravelHawk Pro device will be connected to 1-Gb switch having port mirroring functionality. The switch will be getting all the network data from cable modem EPC3825. TravelHawk Pro will capture and analyze the data then provide network attributes needed by University of Oulu power consumption model.

The power consumption measurement will be then visualized in EXFO TravelHawk Pro UI.

TelHoc will collect power measurement values via the Nexus 5 Maxim MAX17050 HW module, and upload measured values to needed partner components.

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Greenspector Android probe will be installed as an APK on the mobile terminals. Its collected data will be converted in CSV format to be visualized in EXFO UI.

5.3.2.2 Parameters to be measured

The measured parameters of mobile terminal energy consumption is the instantaneous and average power consumption in Watt.

Power consumption in 3G and 4G network in Watts.

Power consumption of the overall system as well as of the process to be monitored. Network activity and memory use.

5.4   End-to-End Energy and QoS/QoE

Partners: **BTH and VTT**

5.4.1.1 Integration Process Description

The partner that need a device to be monitored, states how many 220V main cables are involved. If they want QoS/QoE they also have to provide two wiretaps/span ports that can replicate the ingess/egress traffic to their device/component. The wiretaps/span ports are currently limited to 100 Mbps for practical reasons.

In the case of QoS/QoE the partner also have to state the ingress to egress ratio wrt packets/s or bit/s of their component.

5.4.1.2 Parameters to be measured

The power [W] and accumulated energy [Ws] will be collected and updated every 5s, the data will be available via a Restful API. The QoS parameters will also be available in an InfluxDB.

The energy probes will be calibrated against a 2000kW source before leaving Sweden (compromise to cover low power devices (~5W) to moderate devices (500W), and peaks less than 2kW)

5.4.1.3 Visualization

The energy and QoS results will be visualized in a Grafana dashboard.