SARDANA project

Scalable
Advanced
Ring-based passive
Dense
Access
Network
Architecture

SARDANA showcase

Milan, February 2011

FTTH Council Europe 2011

European Commission, 7th Framework Programme
Activity: FP7 ICT-1-1.1 - Network of the Future
Grant agreement n.217122 (SARDANA)
STREP 2008-2010, 2.6 MEuro

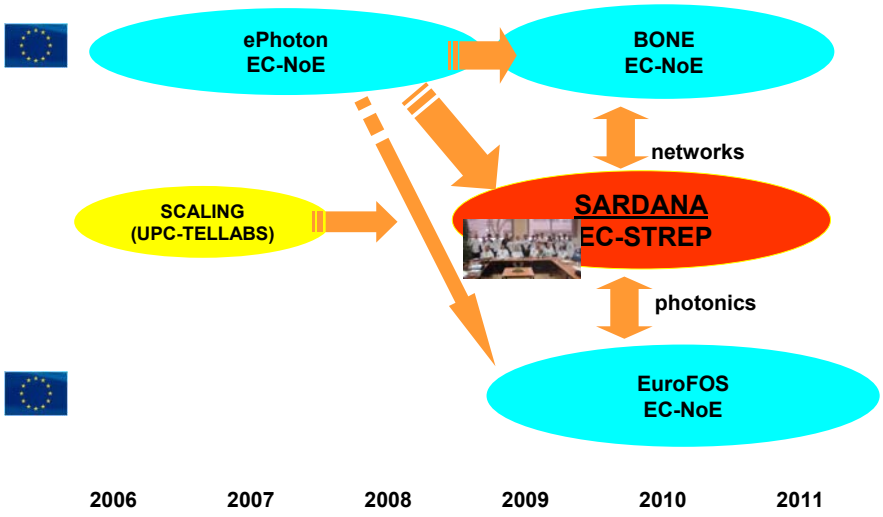
	Participant name	Short name	Country
1	Universitat Politecnica de Catalunya	UPC	Spain
2	France Telecom / Orange	FT	France
3	Tellabs	TELLABS	Finland
4	Intracom S.A. Telecom Solutions	IntraCOM	Greece
5	Instituto de Telecomunicações	IT	Portugal
6	High Institute of Communication and Information Technology	ISCOM	Italy
7	Research and Education Laboratory in Information Tech.	AIT	Greece

ToC

1. Project organization
2. Concept and Architecture
3. Main Results

Back-up

SARDANA pre-history



Partner location, profiles, tasks

Profiles and expertises	UPC	FT	TLB	ICOM	IT	ISC	AIT
Netw.&Serv. Operator		X					
PON equipment provider			X	planned			
Service platform provider				X			
WDM-PON expertise	X	X					
Monitoring techniques					X	X	
Impairment compensation	X						X
Semiconductor photonics	X	X			X		
Remote amplification	X				X	X	
High bit-rate systems					X		X

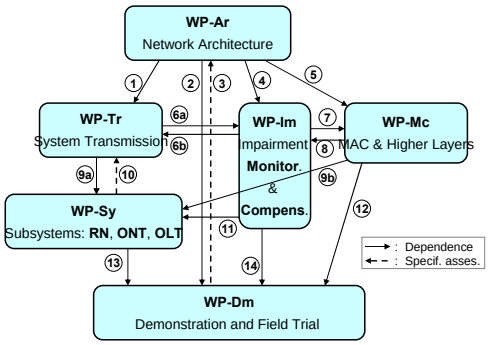
UPC:	Coordination, ONU, RN subsystems.
FT:	Architecture definition, ONU, Field-trial, Technical management, Techno-Economic studies.
Tellabs:	GPON equipment, MAC, lab-demonstration.
IntraCOM:	Management &Control plane, Service platform.
IT:	Monitoring system, non-linear transmission.
ISCOM:	Remote nodes, non-linear amplification.
AIT:	Electronic PON impairment compensation, Techno-Economic studies.

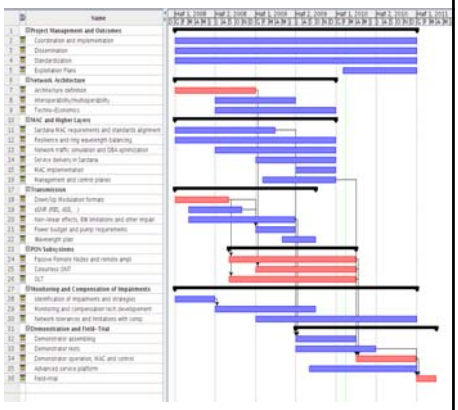
Task-time effort distribution

Project funded by the European Commission with 4.2 / 2.6M€

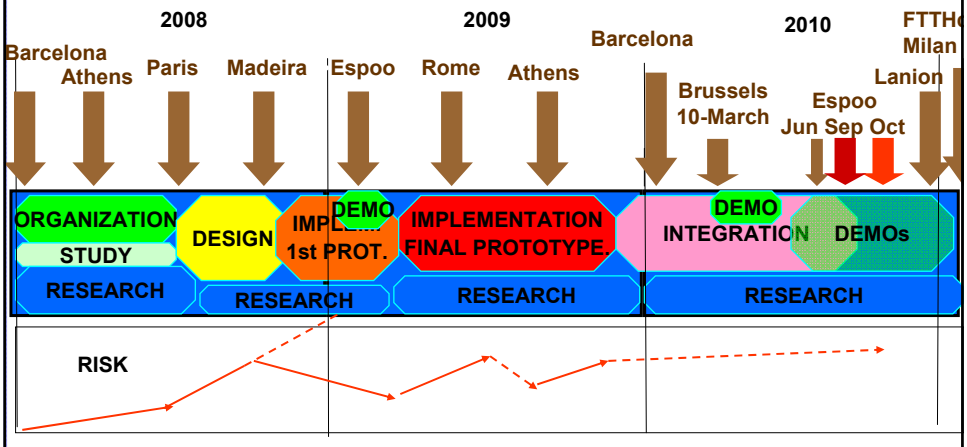
/ 7 partners

/ 3 years





Project phases



- **Prototype and test Phases of Sardana:**
  - **Current GPON-compatible 2.5G/1.25G**
  - **10G/2.5G for Demo**
  - **10G/10G with advanced techniques.**

ToC

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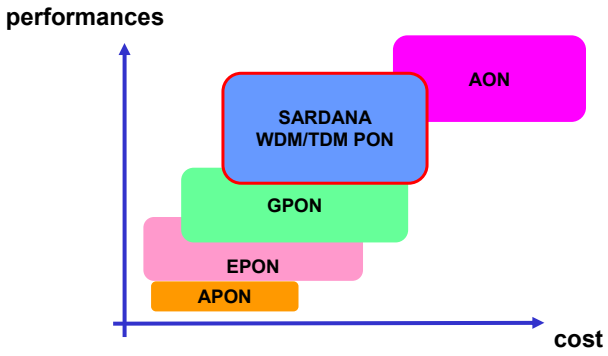
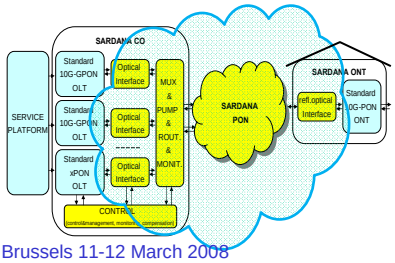
Aim positioning

- SARDANA aims at achieving:
  - higher performances than GPON (L, ONUs, BW, resilience),
  - but at a similar cost (passive PON, reflective ONU, etc).
  - and maximum compatibility with ngGPON



Fundamental goals

- **Maximize:**
  - **N. served users (>1000 per fibre ring)**
  - **Served area (100Km)**
  - **Served capacity (10Gbit/s x 32)**
- **Minimize:**
  - **Infrastructure COST**
    - **N. Fibres / cables**
    - **N. Cabinets**
    - **N. Active areas**
    - **Civil work investments**
- **Musts:**
  - **Passive external plant**
  - **Single fibre access**
  - **Scalability and upgradeability**
  - **Compatibility with g/e-PON MAC**
  - **Robustness:**
    - **Protection**
    - **Monitoring and electronic compensation**



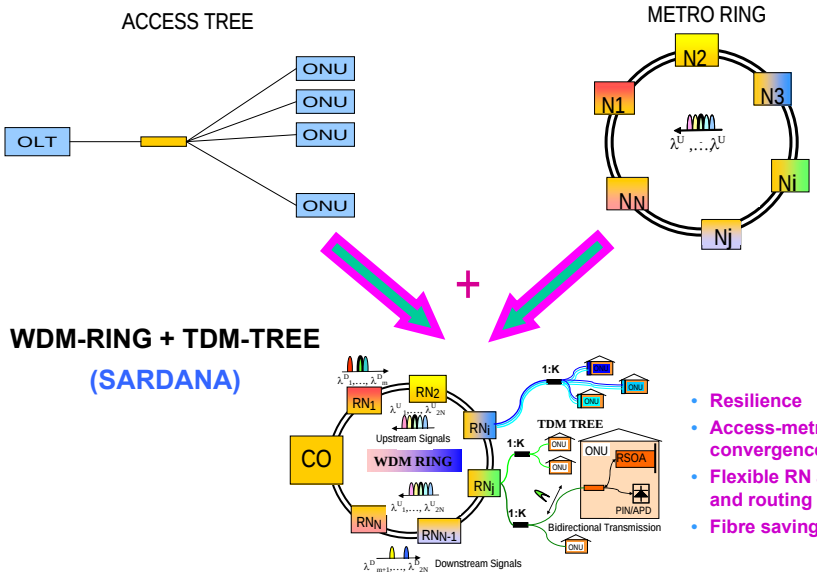
Future Networks Concertation meeting, Brussels 11-12 March 2008

Initiatives towards NG-PON

1. BIT-RATE INCREASE (XGPON, to 10G)
   - IEEE 802.3av Task Force
     - DS:1570nm, US: 1300nm
   - FSAN XGPON 10G/2.5G
2. REACH EXTENSION
   - GPON new TX/RX classes: C (30dB), C+(32dB)
   - ITU-G.984.6 Mid-span Extender (20 to 60 Km)
3. WDM (NUMBER OF CHANNELS / SERVICES):
   - ITU-G.984.5
   - NG-PON-1 (coexistence, same fibre plant)
   - NG-PON-2

+

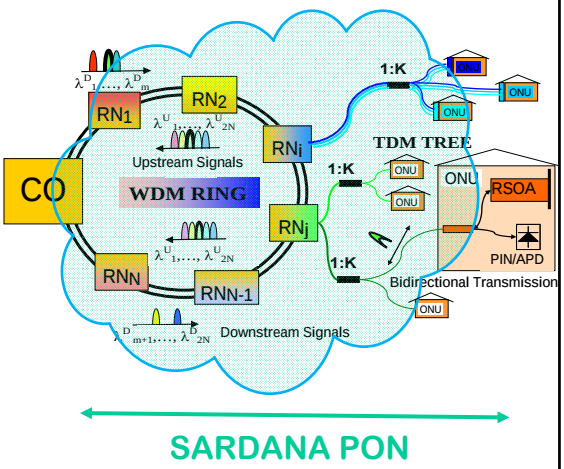
Architecture basis



- Resilience
- Access-metro all-optical convergence
- Flexible RN allocation and routing
- Fibre savings

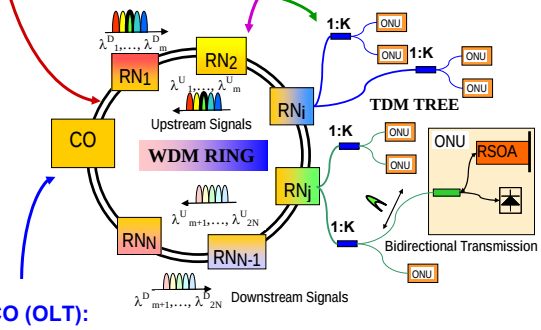
SARDANA architecture def.

- **Resilient trunk**
- **Fully passive**
- **Hybrid:**
  - **WDM Metro ring**
  - **TDM Access trees**
- **Cascadable remote nodes**
- **New adoption of remotely-pumped amplification**
- **Colourless ONU**
  - **RSOA**
  - **Tunable laser**
- **10G-2.5G (1G-100Mb /user)**
- **100 Km**
- **1000 users**
- **Multi-operator**
- **Based on GPON, but transparent.**
  - IP trafic



Approach and basic modules

- **WDM ring: Resilience**
  - (up to 1.2Tbit/s)
- **TDM trees**

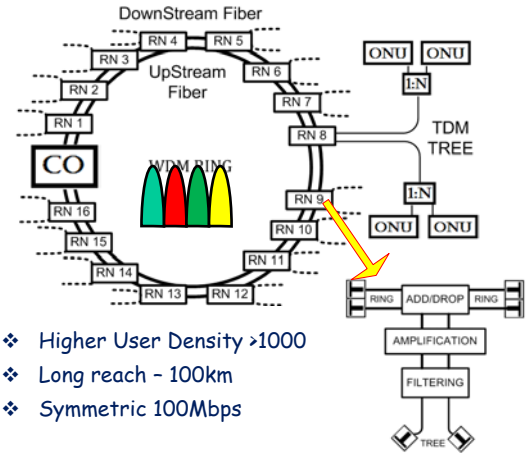


- **CO (OLT):**
  - Centralizes the light generation and control
  - Stack of lasers serving TDM trees
  - Standard G/E-PON equipment adapted to SARDANA

- **Passive Remote Nodes (RN):**
  - Cascadable Add&Drop
  - 2-to-1 fibre interface
  - Remotely pumped (from CO) optical amplification by EDFs
  - Athermal splitters and fixed filters

- **Simple colourless ONU:**
  - Reflective
  - Single fibre & wavelength

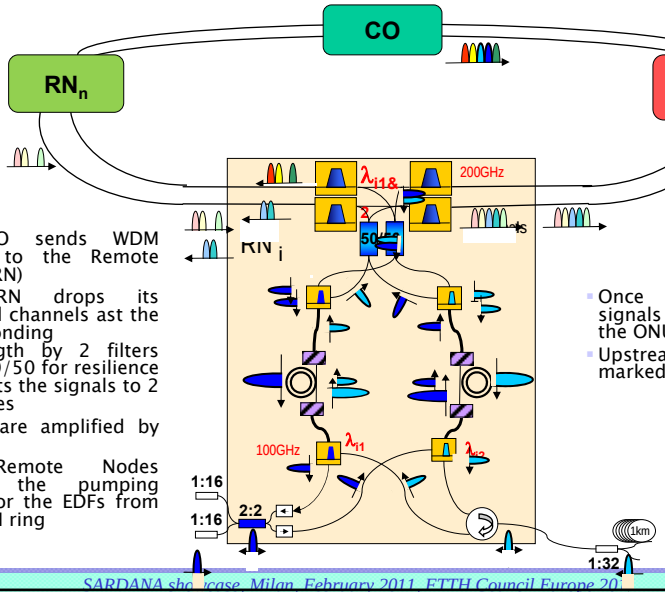
Sardana, how it works



- Higher User Density >1000
- Long reach – 100km
- Symmetric 100Mbps

- Centralized light generation
- Passive Outside Plant
- Scalability
- Resiliency
- Traffic Balance
- Multi Operability
- Remote Amplification

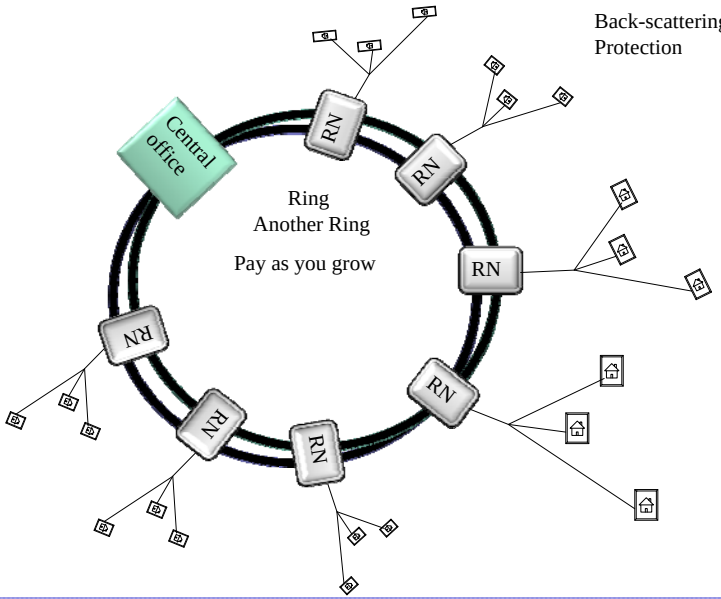
How it works?



- The CO sends WDM signals to the Remote Nodes (RN)
- Each RN drops its assigned channels ast the corresponding wavelength by 2 filters and a 50/50 for resilience that splits the signals to 2 TDM trees
- Signals are amplified by EDFs
- The Remote Nodes receive the pumping power for the EDFs from the WDM ring

- Once amplified, the signals are transmitted to the ONUs
- Upstream signal path is marked with static figures

The evolution towards... Scalability

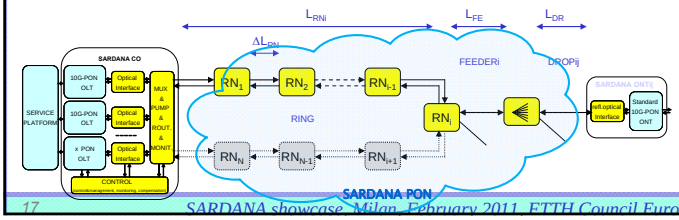


Scenarios for dimensioning study cases

Depending on :

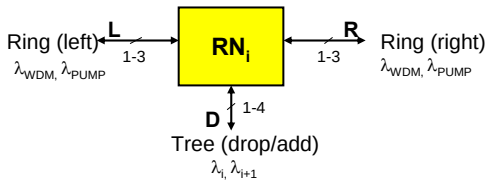
- Scenarios
- Available technologies,
- PON standards,
- Performances aimed.

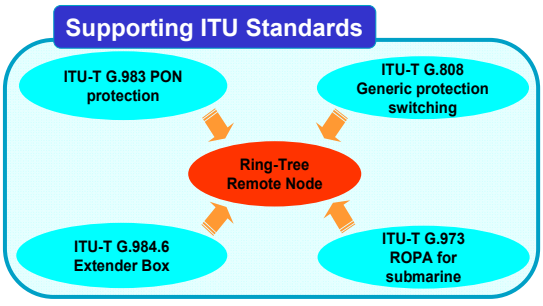
Scenarios	Max distance Km	Ring Km	Tree Feeder Km (max)	Tree Drop Km	Trees (λs) (2xRN)	Splitter	ONUs	Guar. BW (10G)	Pump (W) Goal tbd
URBAN 1	20	17	2.9	0.1	32 (2x16)	1:64	2048	>140M	1.2
URBAN 2	20	10	9	1	32 (2x16)	1:32	1024	>280M	1.2
METRO	60	50	9	1	16 (2x8)	1:32	512	>280M	1.2 / 5
RURAL	100	80	19	1	16 (2x8)	1:16	256	>560M	5
COLLECTOR	20-60	80	19	1	16 (2x8)	1:8	128x	300M / 1G	
WDM-PON		80	-		32	-	32	10G	



Remote Node as new Network Element

- **"Transparent Ring-Tree WDM/TDM-PON Architecture" (proposal of Sardana architecture for NGPON2),** *Kyoto ● November 2009*





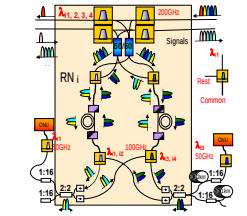
The presented ring-tree ngPON2 architecture enables resilient 10G/2.5G access to scalable 1024 customers distributed in 100Km with 32 wavelengths, achieving:

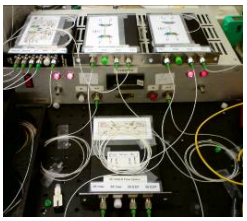
- **higher performances**
  - **L, ONUs, BW, resilience**
- **at a similar cost**
  - **passive PON, refl.ONU..**
- **maximum compatibility**
  - **with ngPON**

Remote Nodes

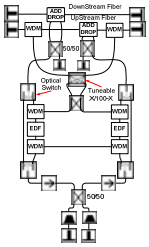
- Add/drop
- Diversity resilience
- Interface:
  - Ring – tree
  - 2 – 1 fibre
- Passive (no powering)
- Remotely pumped optical amplification
- 2 wl dropped
- Burst tolerant
- Fixed / Reconfigurable

FIXED



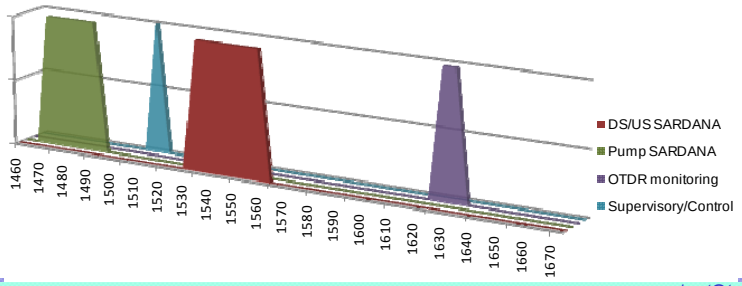


RECONFIGURABLE



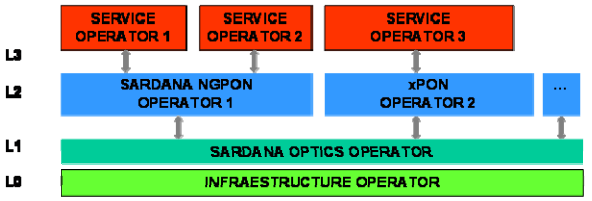
Wavelength allocation

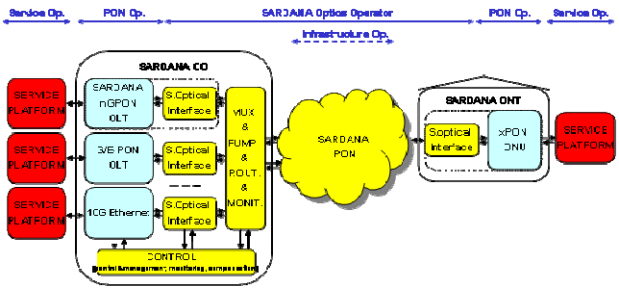
- In SARDANA there is a significant dependency of:
  - the power budget
  - on the wavelength allocation of US/DS channels
  - on the pump generation for remote amplification.
- SARDANA wavelength allocation plan
  - possible compatibility with XGPON1
  - not with video overlay



SARDANA inter-operability & multi-operability

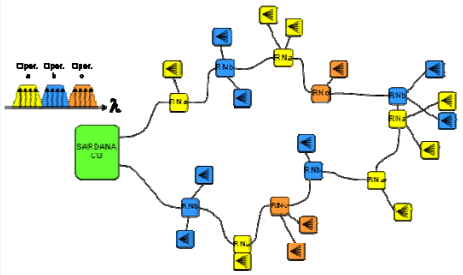
- Proposal of multi-operability models



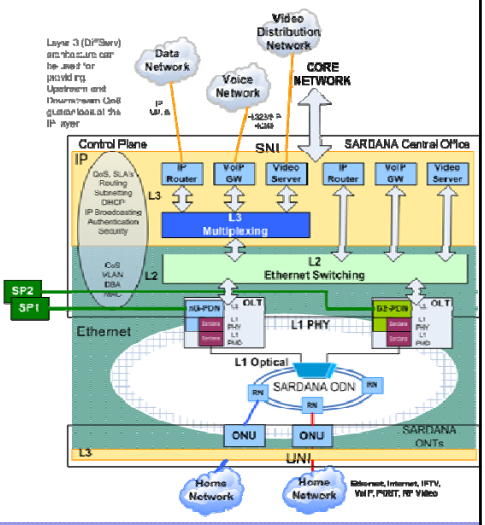


SARDANA multi-operability

Physical layer

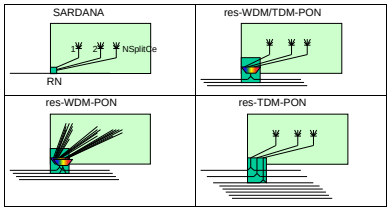


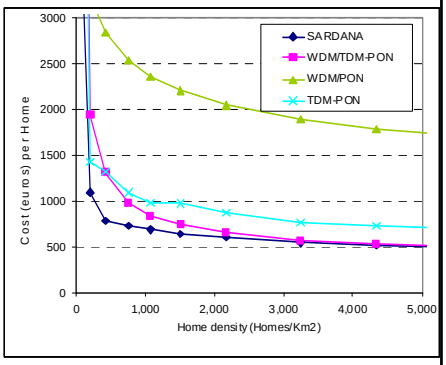
L2/L3



Techno-economics aspects

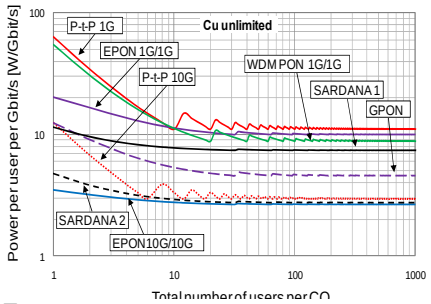
- CAPEX
  - Analysis of:
    - PASSIVE:
      - Fibre infrastructure
      - Remote Node
    - ACTIVE:
      - ONU
      - OLT
      - Pump
      - Monitoring and protection
  - Active equipment price estimation and learning curve
  - CAPEX (overall for SARDANA & GPON): Cost/user vs. density
- SARDANA is cost effective in a wider range of user densities.

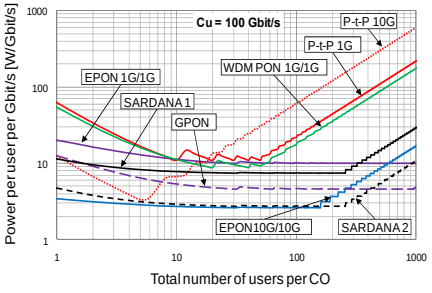




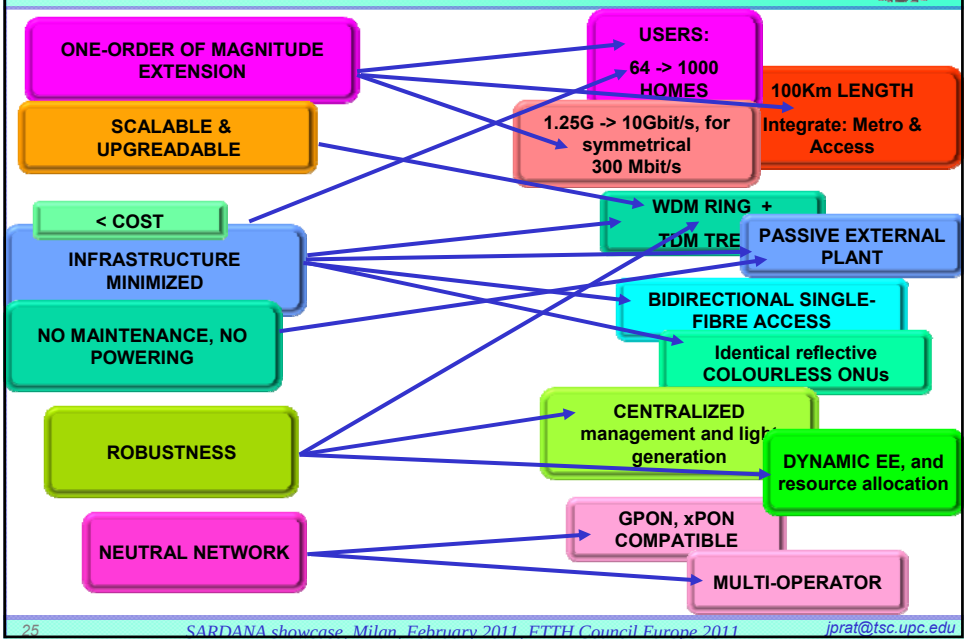
SARDANA GREEN TOUCH

- Deep analisys has been performed in order to compare the SARDANA approach with the main access technologies.
- In principle two SARDANA situations have been considered: SARDANA1 and SARDANA2. First one is SARDANA with “non commercial” devices. Second is SARDANA with market ready components.
- In figure are reported the results for unlimited and limited upstream. SARDANA, especially the version 2, express the best performances in terms of power efficiency.





Goals vs Approach



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   1. Research
   2. Publications
   3. Development
   4. Demo

Transmission issues and proposed solutions

PROBLEM	PROPOSED SOLUTION	REF
Rayleigh BS & reflections	Wavelength shifting at ONU by SC-SSB	JLT 9-09 (pat)
"	Wavelength Conversion via Four-Wave Mixing in SOA-based ONUs	OFC'10 OThG4, JLT
"	OLT wavelength dithering	ECOC P421
"	Optimal MUX positioning and ONU gain	PTL 1-10
" + burst mode	Rayleigh Back-scattering reduction by means of Quantized Feedback Equalization in WDM-PONs	ECOC'10
Limited BW of RSOA	Chirped-managed RSOA with offset-filtering and DFE/FFE 10G	OFC'09 OThA7
"	RSOA electronic equalization using MLSE at 10G	OFC'10 OWG2
"	Uncooled DML + EE	OFC'09 OWE3
"	Direct 10-Gb/s Modulation of a Single-Section RSOA in PONs With High Optical Budget	JLT, 7-2010.
Wavelength reuse crosstalk	Integrated colorless optical FSK demodulation with Fabry-Perot SOA/REAM at 10G	ECOC'09 We7.5.6 (pat)
	Multiple Down-stream cancellation techniques…	ECOC'09 We8.5.4
"	Periodic filtering at ONU	OFC'10 OWG4 (pat)
"	Colourless SCM/IM	NFOEC'10 NWB5

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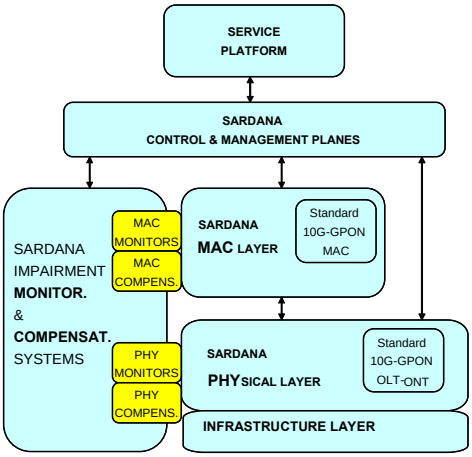
PROBLEM	PROPOSED & SHOWN SOLUTION	REF
WL reuse + disper.	SSB with Manchester coding	ECOC'09 P6.26
Fibre non-linearities	Genetic algorithm for wavelength and power allocation	OFC'09 JThA77
BW inefficiency	Homodyne PSK	OFC'10 JThA3 (pat)
Limited reach	RN EDFA Pump from ONU ASE	OFC'10 JThA33
"	Reconfigurable RN	ECOC'08 (pat)
"	Active/Passive Extender Box	JOCN 9-09
"	C+L mixed pump	ECOC'09 We.P6.19
"	Energy-Efficient Optical Access Networks Supported by a Noise-Powered Extender Box	ECOC'10 (pat)
Split + Reach + 10G bidirectional	Self-Pumped Dense (40λ×32 split) PON with Extended 30 dB Loss Budget and ONUs Comprising a 10 Gb/s RSOA	ECOC10
EDF transients	Burst pre-carving	ECOC'09 We.P6.24
Cost efficiency	Quantitative Techno-economic Comparison of Current and Next Generation Metro/Access Converged Optical Networks	ECOC'10

- > 70 international publications
- 4 patents applications
- Invited papers to OFC, ECOC, OSA-ANIC, ICTON, MIT,

Multilayer integrated network

FUNCTIONALITIES:

- Resilience
- Multi-operator capability
- Multi-rate coexistence
- OMC Control&Management plane
- 10G XGPON MAC
- DBA (simulation)
- In-service monitoring
- Impairment-aware routing
- Eye-safeness



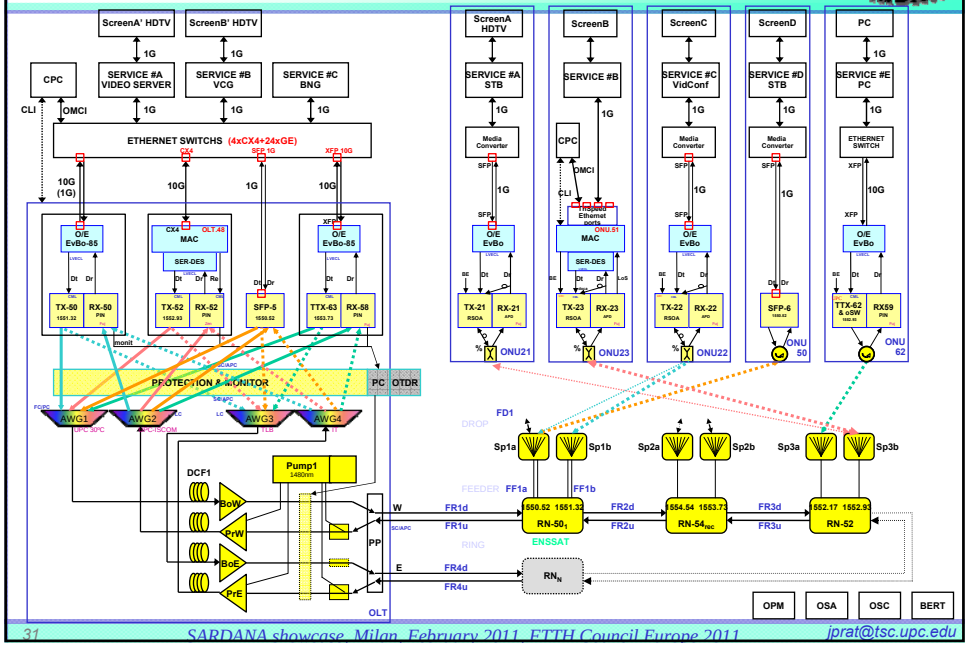
Functional layered model of SARDANA.

→ **Multilayer testbed**

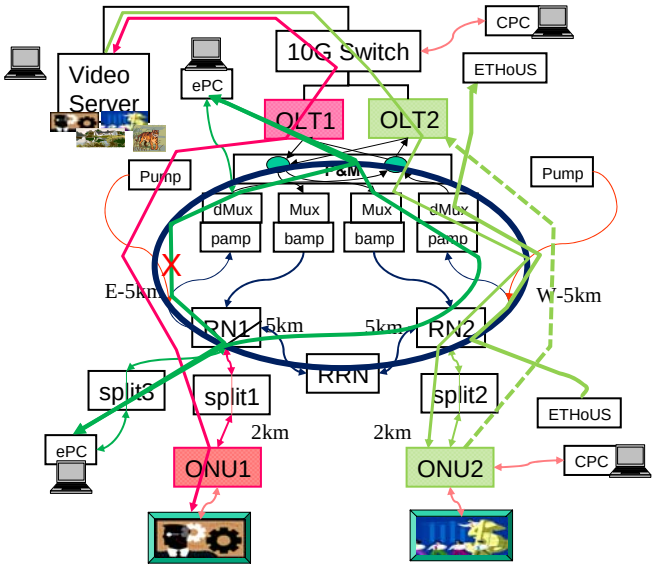
From Espoo to Lannion

- The stakeholder demo took place in Espoo Finland 28-10-10
- Services over SARDANA were successfully demonstrated
- Experience from the demo was used to improve the system performance
  - MAC operation Upstream and Ranging
  - Burst transmitter optics
  - Protection and monitoring system
- System was shipped to Lannion in early December
  - Reintegration took place December to January

SARDANA testbed



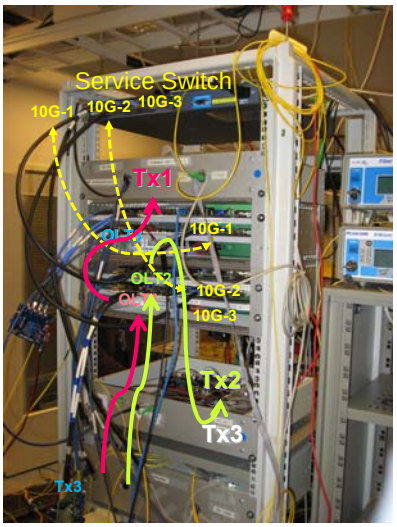
Espoo demo setup 21.-28.10



Demos:

1) HD-video DS
2) HD-video US
3) p2p Ethernet
4) Protection switch
5) Service control

Espoo - OLT- MAC and TX1/TX2



The services and management connect to the Service switch 1GE ports (on the back)

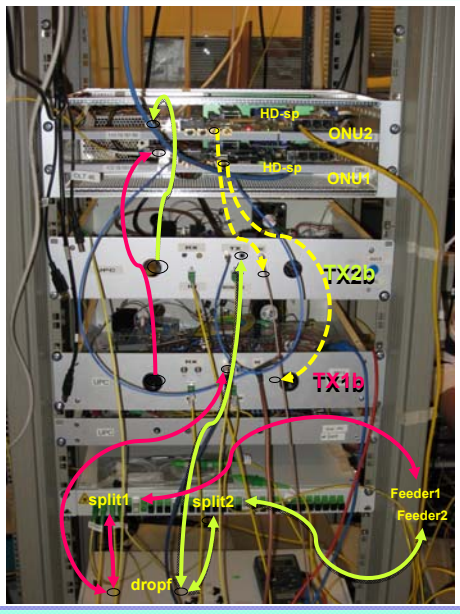
1) Service switch connects to OLT1-OLT2 MAC via 10GE (CX4) ports.

2) OLT1-2 MAC connects to TX1-TX2 downstream transmitters via fiber.

3) TX1-TX3 connect via multiplexers to the downstream ring fibers.

4) OLT MAC RX1-2 connect from upstream ring fibers via demultiplexers

Espoo ONU – MAC and TXb



1) CPE STBs connect to ONU High defintion video service port (HD-sp).

2) The ONU1-2 MAC connects to TXb1-2 via SMA cabling.

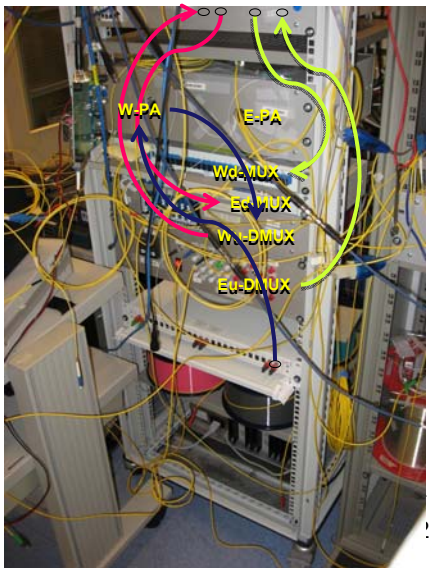
3) The ONU1-2 MAC RX connects to RX1-2 with fiber.

4) TXb1-2 connects to drop fibers (2-5km).

5) Drop fibers go to splitters 1-2 which connect to feeder fibers.

6) Feeder fibers (5-15km) connect to the RN1-2.

OLT- DWDM MUX/DEMUX



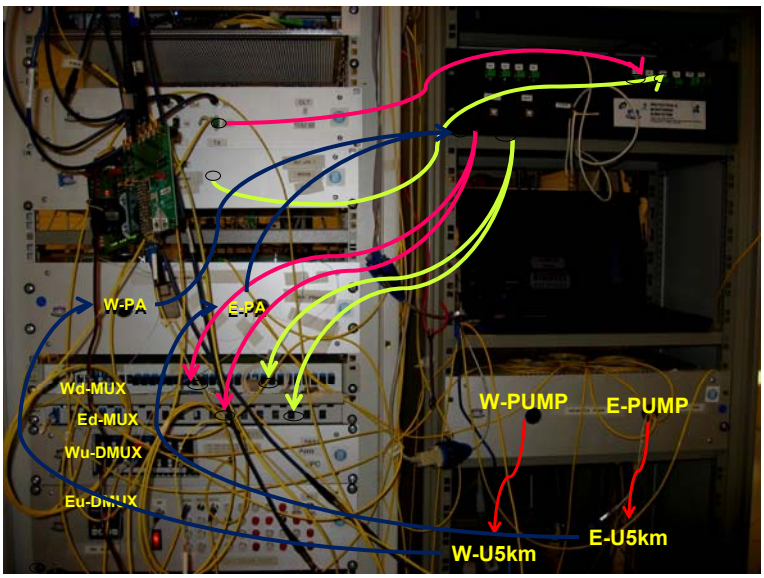
1) The OLT TX1-2 connect DS to either East or West DWDM MUX

2) The OLT RX1-2 connect US to either East or West DWDM DEMUX
When the protection and monitoring system is used the connections go via it.

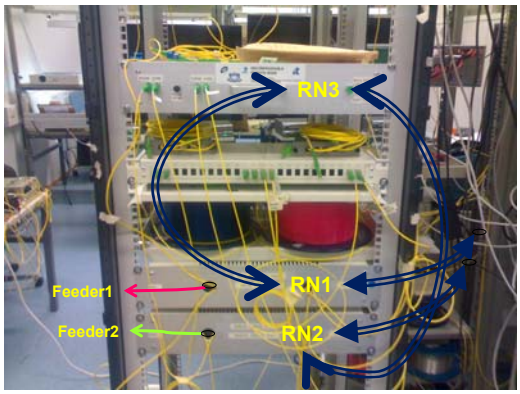
3) There is a pre-amplifier (PA) upstream for all wavelengths before the DWDM DEMUX.
There is also a boost amplifier (BA) downstream for all wavelengths after the DWDM MUX.

4) DS and US fiber spools (5-25km) run between the OLT and the RN1-2

OLT- P&M + DWDM MUX + PUMP



RN1-3



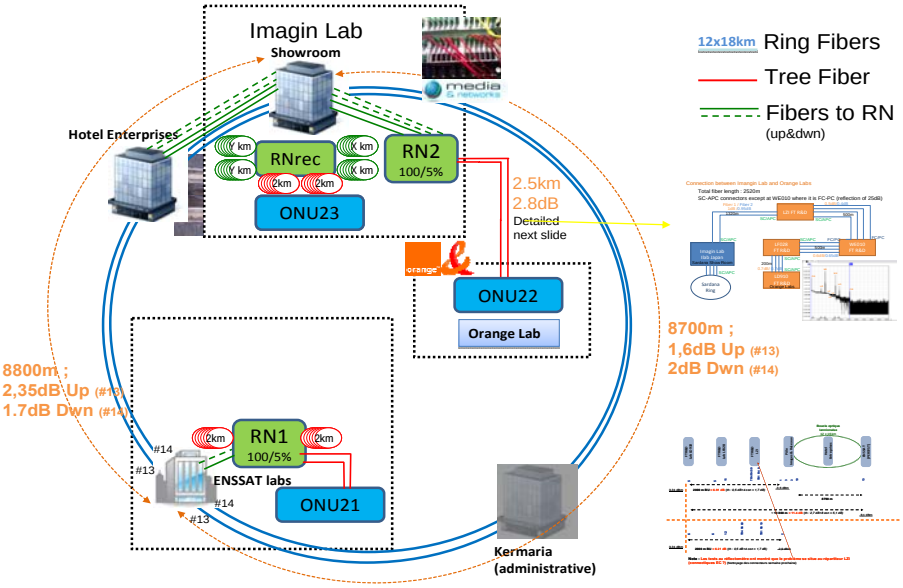
From Espoo to Lannion

- The demo system in Espoo had all the equipment co-located
- Lannion trial has distributed equipment on several sites
  - This makes it more challenging and exciting
- We continue to improve the robustness as we go from Lannion to FTTH Council in Milan
  - Next week testing continues

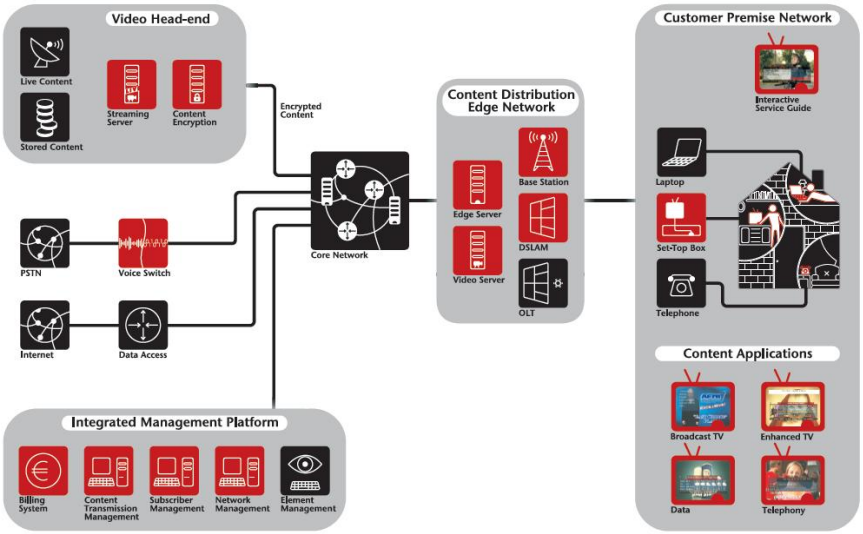
SARDANA Field-Trial *(Lannion, 20th January 2010)*

- The Orange Labs facilities are connected to a 18 Km "open" fiber network.
- This fiber network is located along the Bretagne Lannion area, and managed by the cluster Media&Network.
- 12-fibre ring cable plus distribution trees.
- Reintegration of SARDANA systems took place December to January

Field trial fibre connectivity



Service Delivery with *fs/cdc*



Field trial tests

- SARDANA network transmission over 55 Km, over the deployed Lannion area cable infrastructure plus extra local spools.
- Optical connections between ImaginLab, ENSSAT and OrangeLab.
- Different communications services transmitted through:
  - 2x Bidirectional 1G Ethernet using RSOA and SFPs.
  - 10G / 2.5 XGPON scrambled burst data.
  - Bidirectional 10G Ethernet using tuneable laser ONU.
- Functionality shown:
  - Channel protection (fibre cuts).
  - ONU colourlessness.
  - Multi-operability.
  - High bandwidth real time bidirectional HD multimedia services.

Final Outcomes

- SARDANA project targets the ultimate extension of the limits of FTTH Passive Optical Networks, as a practical transparent approach to access&metro convergence.
  - Sardana Test-Bed Demonstration in Espoo-Finland (28-Oct-2010)
  - Sardana Field-Trial in 12-2010 in Lannion-France, with new broadband services (20-1-2011)
  - **Public Demo at FTTH Council Conference, Milan (9/10-Feb-2011)**
    - **FTTH SHOWROOM (YELLOW-2)**
- Network/system/subsystem/component design guidelines and prototypes for NGPON2.
- Contribution to:
  - Regulatory Bodies on Broadband Access to citizens (multi-operator infrastructure sharing strategy, etc).
  - International Standards on next-generation FTTH like NGPON2.

Things for continuing R&D

- RSOA technology has to evolve, for higher GAINxBW, (and injected power) from current:
  - 14 dB 1.2 GHz (TO-CAN), equalized for 2.5Gbit/s
  - 18 dB 0.8 GHz (TO-CAN)
  - 10 dB 3 GHz (Butterfly)
  - -10 dB 10 GHz (REAM)
  - 5 dB 10 GHz (SOAREAM chip)
- FEC has not been implemented and would be convenient.
- Connectors are critical (return loss near ONU, high-power at ring)
- A secondary pump source is convenient to reach 100 Km
  - Or from ASE from SOAs, as has been demonstrated.
- Rayleigh back-scattering is critical for distribution > 6Km.
  - Increase ring, decrease drop, 2 fiber-feeder.
  - Also can be reduced with several techniques developed.
- Many ideas have come up along the 3 years for future improvement.
- 1-2 year for Development.
- _x_? for Deployment

Thank you

from all SARDANA partners !!

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