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State-of-the-art of home networking

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State-of-the-Art of Home Networking

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ECOC2012 Symposium on Indoor Optical Networks, Amsterdam, Sep. 17, 2012

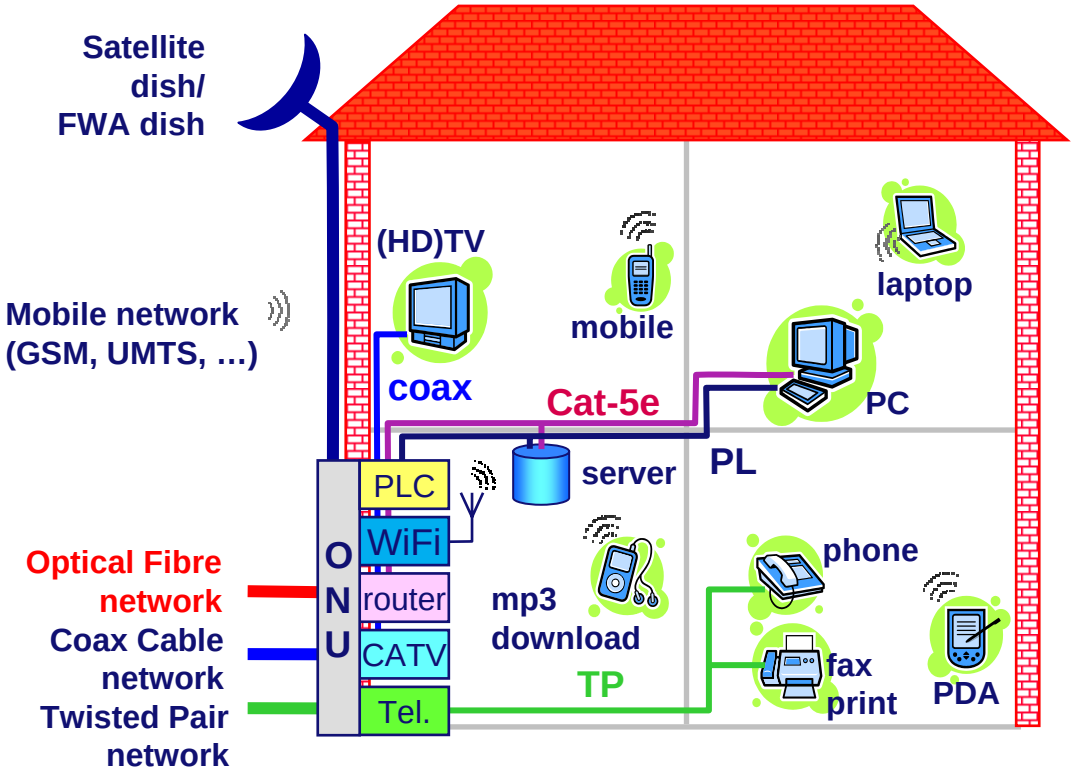
Outline

- Convergence in home networks
- Home service scenarios
- Home wired network architectures, CapEx and OpEx
- Advanced network techniques
- Evolution trends and roadmap
- Concluding remarks

Today's in-home networks

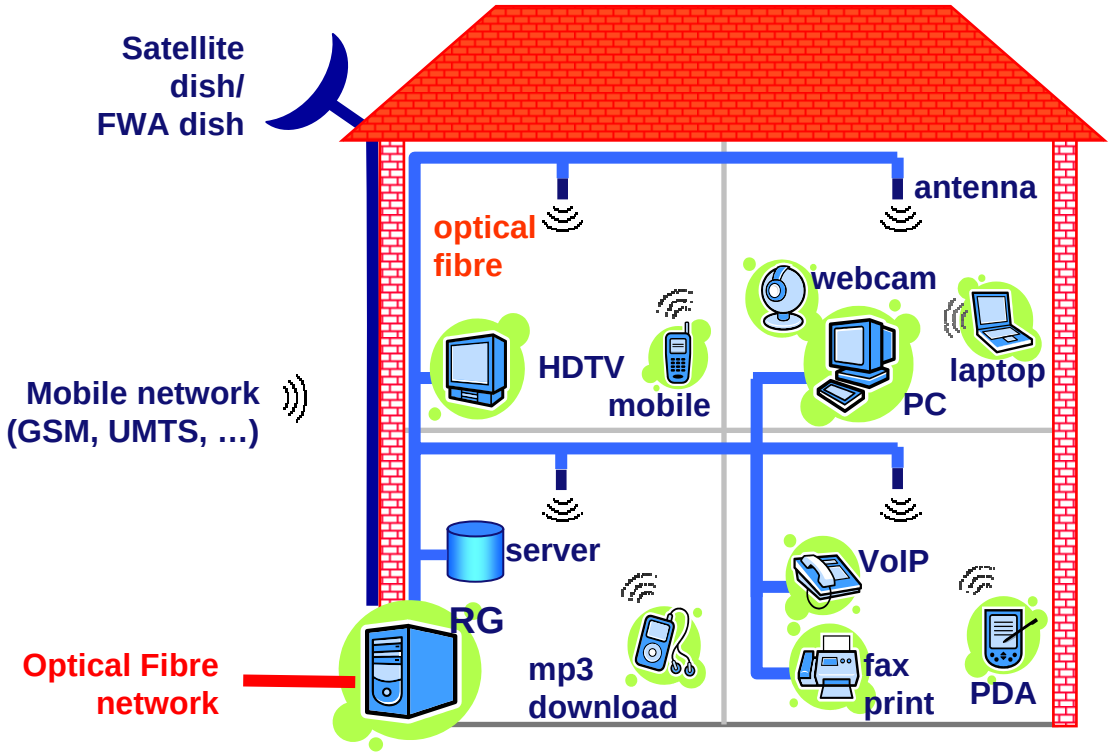
A variety of networks:

- **Twisted pair copper lines:**
  Telephone, fax, …
- **Coaxial copper lines:**
  CATV, videorec, radio, …
- **Cat-5 cables:**
  PC-s, routers, hubs, printers, servers, …
- **Wireless LAN:**
  Laptops, PDAs, …
- **Infrared:**
  remote control TV/videorec/radio/…



⇨ Complicates maintenance, upgrading, running of services on multiple platforms, interoperation of services, …

Converged in-home network: with fibre

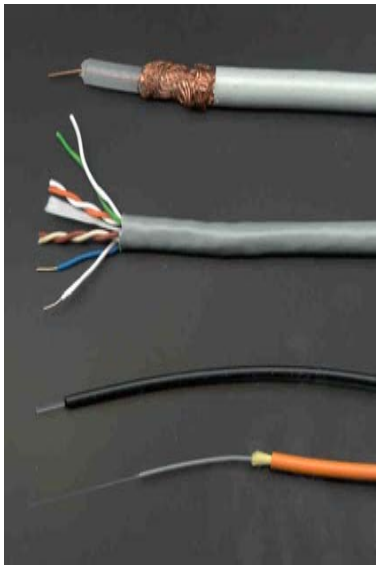


Coax

Cat-5E

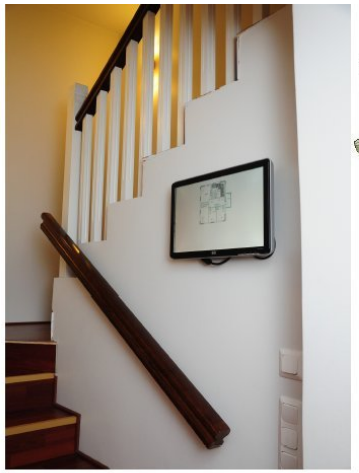
POF

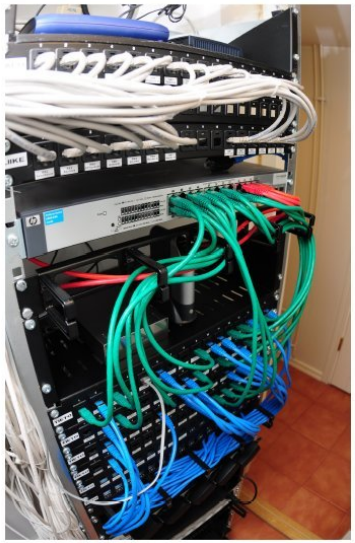
SMF

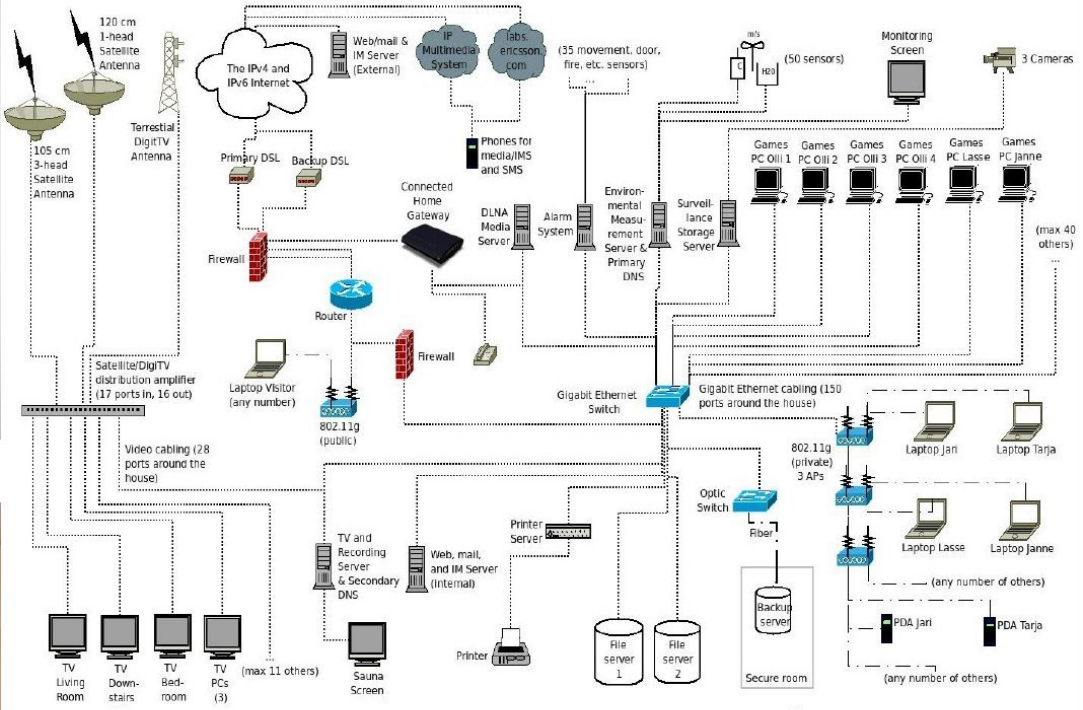


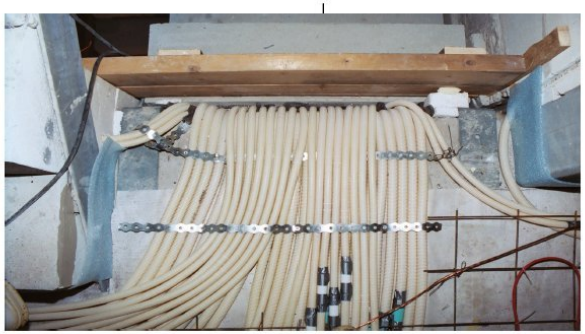
- fibre backbone: silica SMF, MMF, or large-core POF
- integrate wired and wireless services (by e.g. WDM) in a single network
  - ⇨ reduces installation and maintenance efforts
  - ⇨ eases introduction and upgrading of services

It can get quickly very complex:









- 200 Gb Ethernet ports
- 4 kilometres of Cat6 cable
- IPv6
- Enables “laundry talking via Facebook”

Source: Jari Arkko, http://thingsonip.blogspot.se/2012/04/home-networks-by-magic.html

Video drives bandwidth demand

576i

4-6 Mb/s

1080p

10-15 Mb/s

"4K/8K"

More than 100 Mb/s

1960 *2005* *Shortly after ECOC 2012*

If we add:

- Mobile backhaul and fronthaul (delay budgets in order of 10 ms, bandwidths up to Gbit/s for CPRI/OBSAI)

and

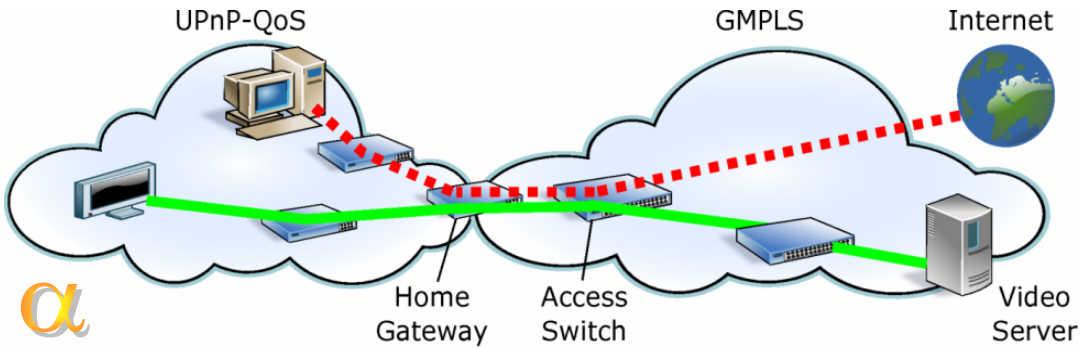
- Local backup to NAS
- Remote backup to cloud
- Web-browsing
- IP telephony
- E-mail and so on...
- All of the above from 10-20 devices (as of today)

- Plus sensors, video surveillance and other Internet of Things gadgets

All the above do not fit neither in copper nor wireless!

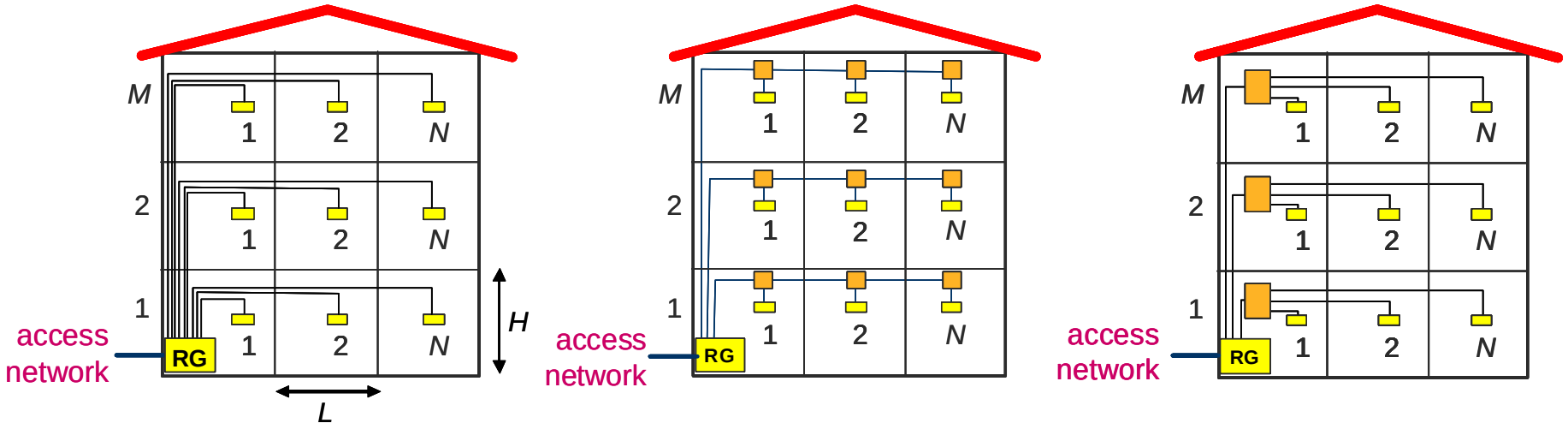
Home Gateway

- Bridges between public access network and in-home network
- Translate IP addresses and modulation formats
- Assures security and privacy
- Provides access to third parties for maintenance and upgrading
- Provides QoS control for indoor terminals
- May host home-internal functions (local data storage, interoperation of devices…)



"Home Gateway can communicate QoS data between access and home domains"

Network architectures



P2P **bus** **tree**

- + hybrid architectures
- **opaque** (with OEO conversions),
  or **all-optical** (with power splitting or λ-routing)

Amsterdam ecoc 2012

CapEx and OpEx

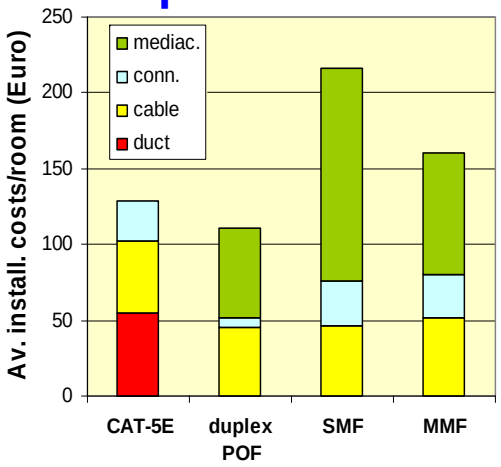
Assumptions:
- opaque network
- fibre solutions share existing duct of electricity wiring

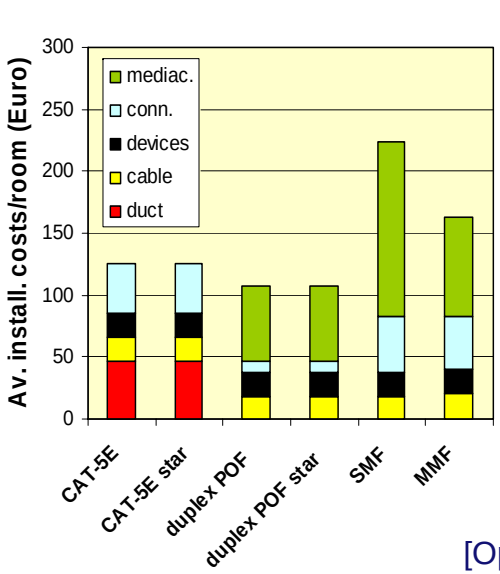
Residential home
- 3 floors, 4 rooms/floor
- P2P network

Office building
- 10 floors, 50 rooms/floor
- bus network

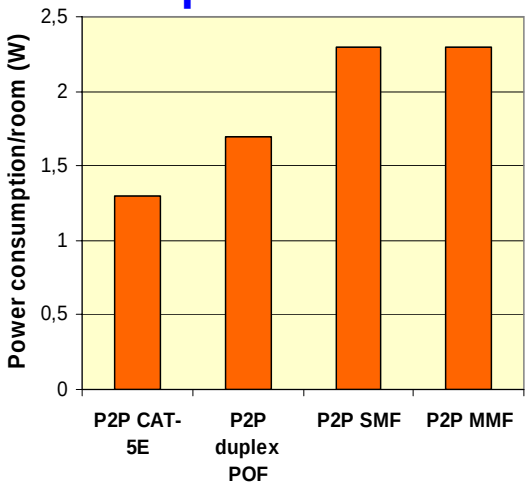
POF outperforms SMF and MMF, and is cost-competitive with Cat-5E

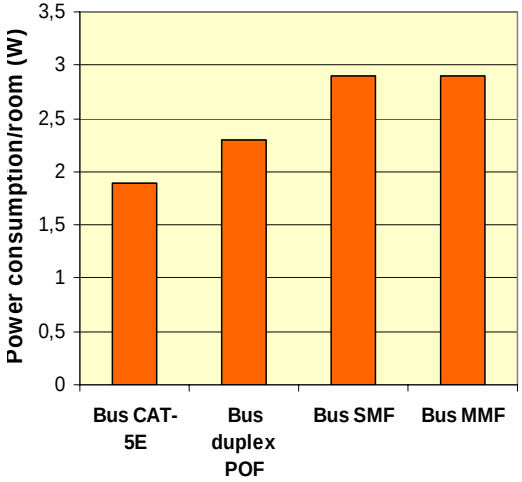
Installation costs per room





Power consumption per room





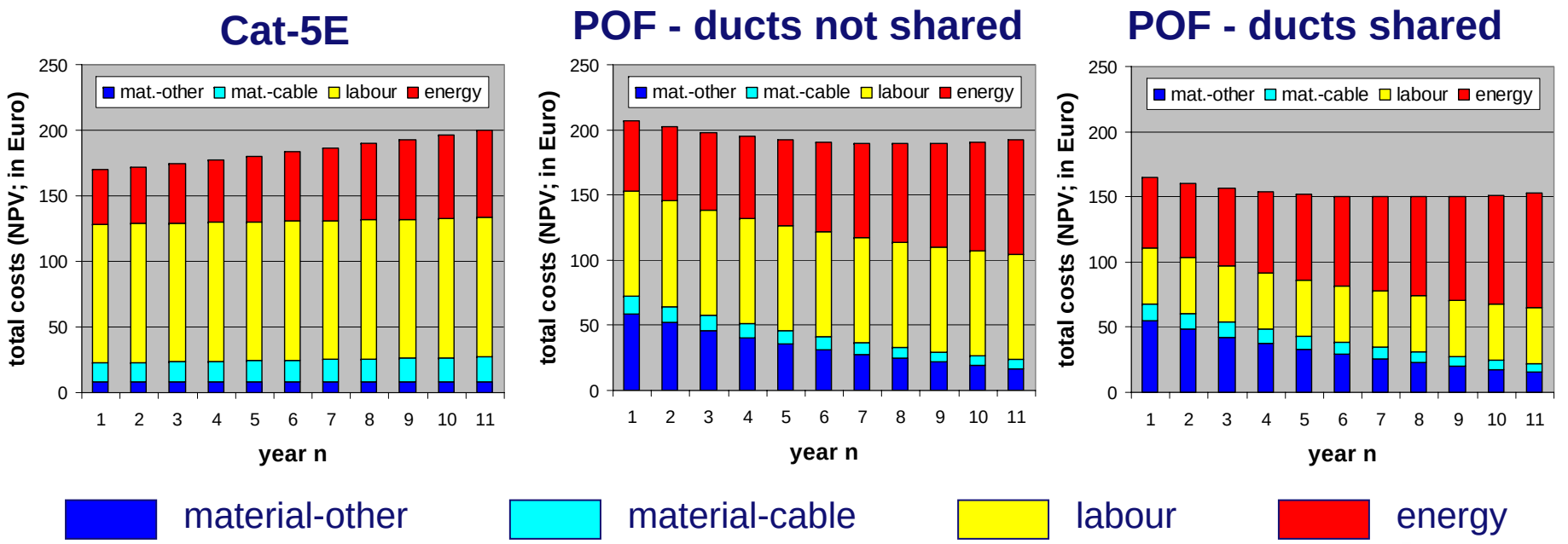
[Optics Express Dec. 2011, Koonen et al.]

Evolution of total network costs

- CapEx + OpEx, Net Present Value
- for residential home during economic lifetime of 25 years
- when installing in year *n*

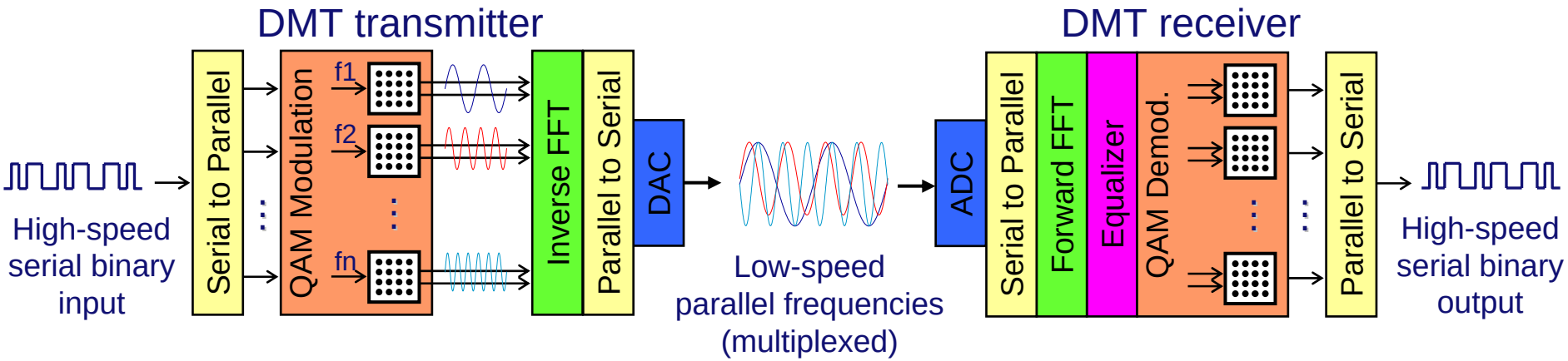
Assumptions:

- Costs of labour +2%/year, of POF products -10%/year, of Cat-5E products +2%/year, of Cat-5E cable +5%/year, of energy +5%/year
- Material/labour costs: duct 10/90%, cable 30/70%, devices 90/10%, connectors 10/90%, media conv. 90/10%



[Optics Express Dec. 2011, Koonen et al.]

High data rates over dispersive POF links



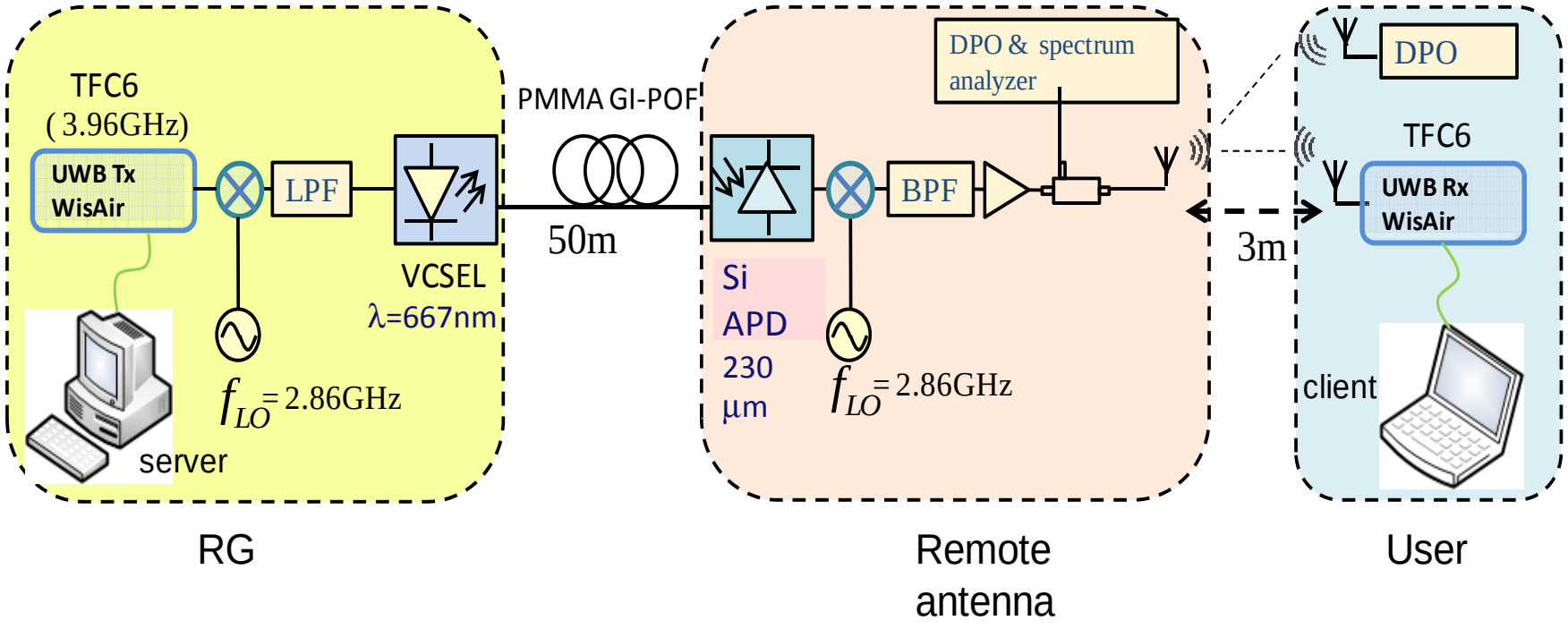
- *E.g. by Discrete Multitone (DMT) modulation:* high-speed serial data transmitted parallel at low-speed using different frequencies
- *high spectral efficiency* with multi-level QAM, not only "on-off"
- especially suitable for *multipath dispersive channels* such as MMF and POF
- 51.8Gbit/s over 100m Ø50µm core PF GI-POF [1]
- 4.7Gbit/s over 50m 19-cores Ø1mm PMMA SI-POF [2]
- 5.3Gbit/s over 50m Ø1mm core PMMA GI-POF [3]

SIEMENS

[1] H. Yang et al, OFC2009, Postdeadline paper PDP8
[2] H. Yang et al, OFC2010, paper OWA4
[3] D. Visani et al, OFC2010, Postdeadline paper PDPA3

UWB radio over ∅ 1mm core GI-POF

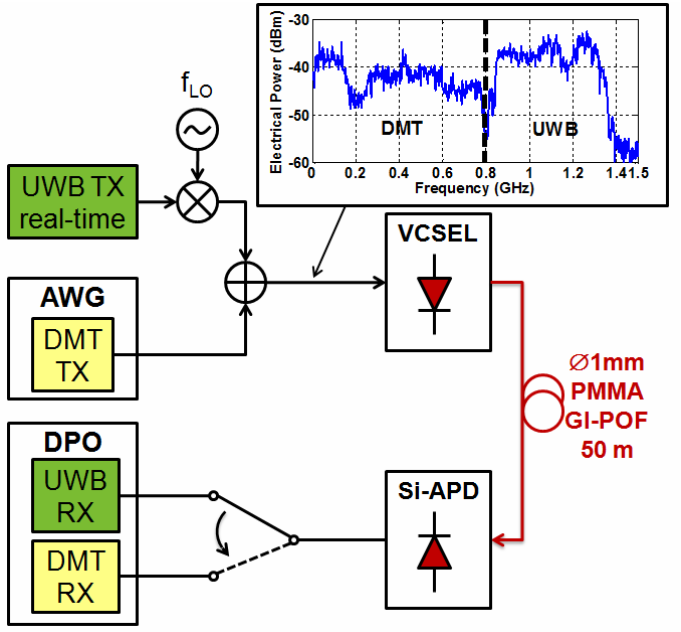
- Real-time HD video over 50m ∅1 mm core GI-POF + 3m wireless
- 528MHz UWB (TFC6, 3.696-4.224GHz)
- Downconversion to 0.836-1.364GHz band
- EVM B2B 9.7%, after 50m GI-POF <15.5%

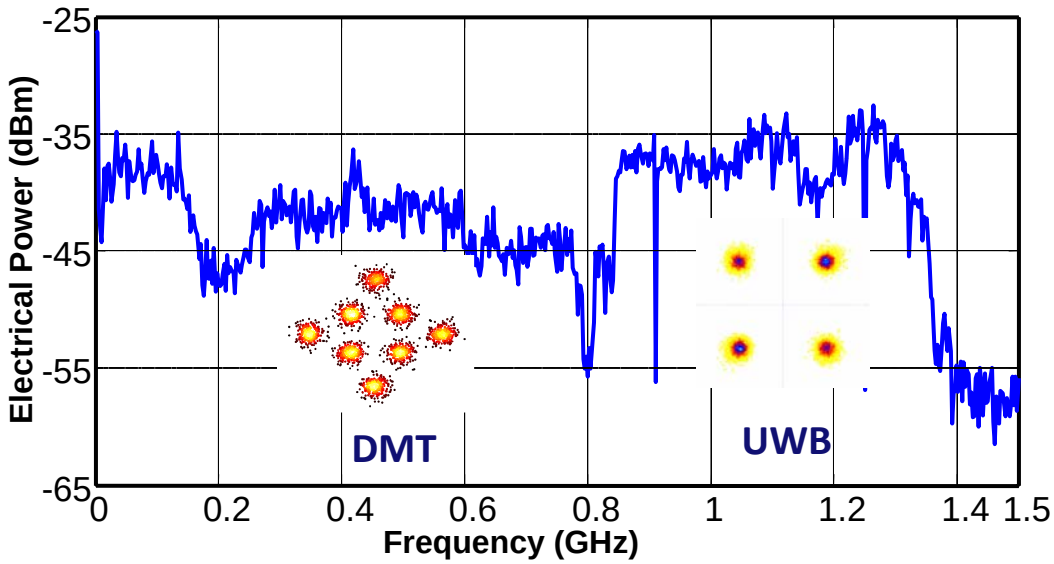


Highly spectrum-efficient reach extension of UWB over GI-POF

[Y. Shi et al, OFC 2011]

Wirebound + wireless services over POF



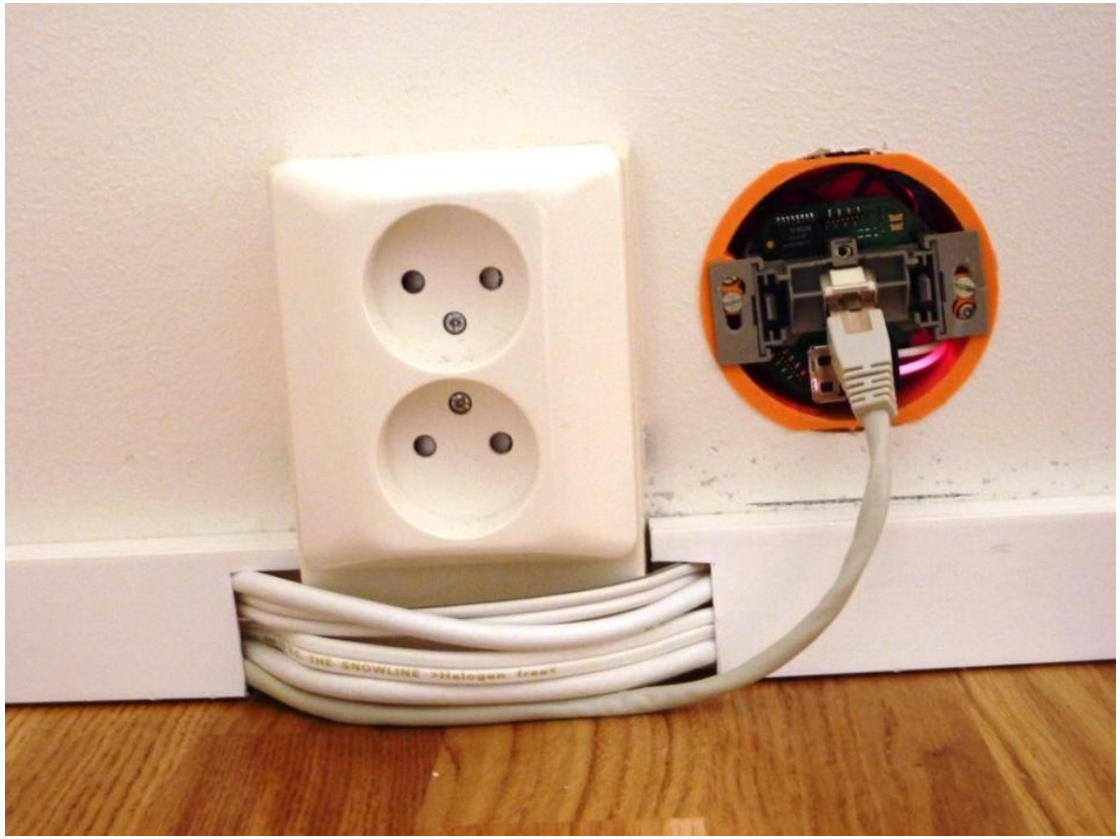


- Wired signals DMT and wireless UWB
- Bandwidth split to DMT (0–0.8 GHz) and UWB (0.85–1.4 GHz)
- UWB bitrate 480 Mbit/s (max) and DMT rate adaptive
- Transmitter VCSEL -1 dBm λ=667nm
- Detector Si-APD with ∅230-µm active area
- 50-m ∅1-mm core graded-index POF

Converged transport of high capacity wirebound and wireless signals

[E. Tangdiongga et al, OFC 2011]

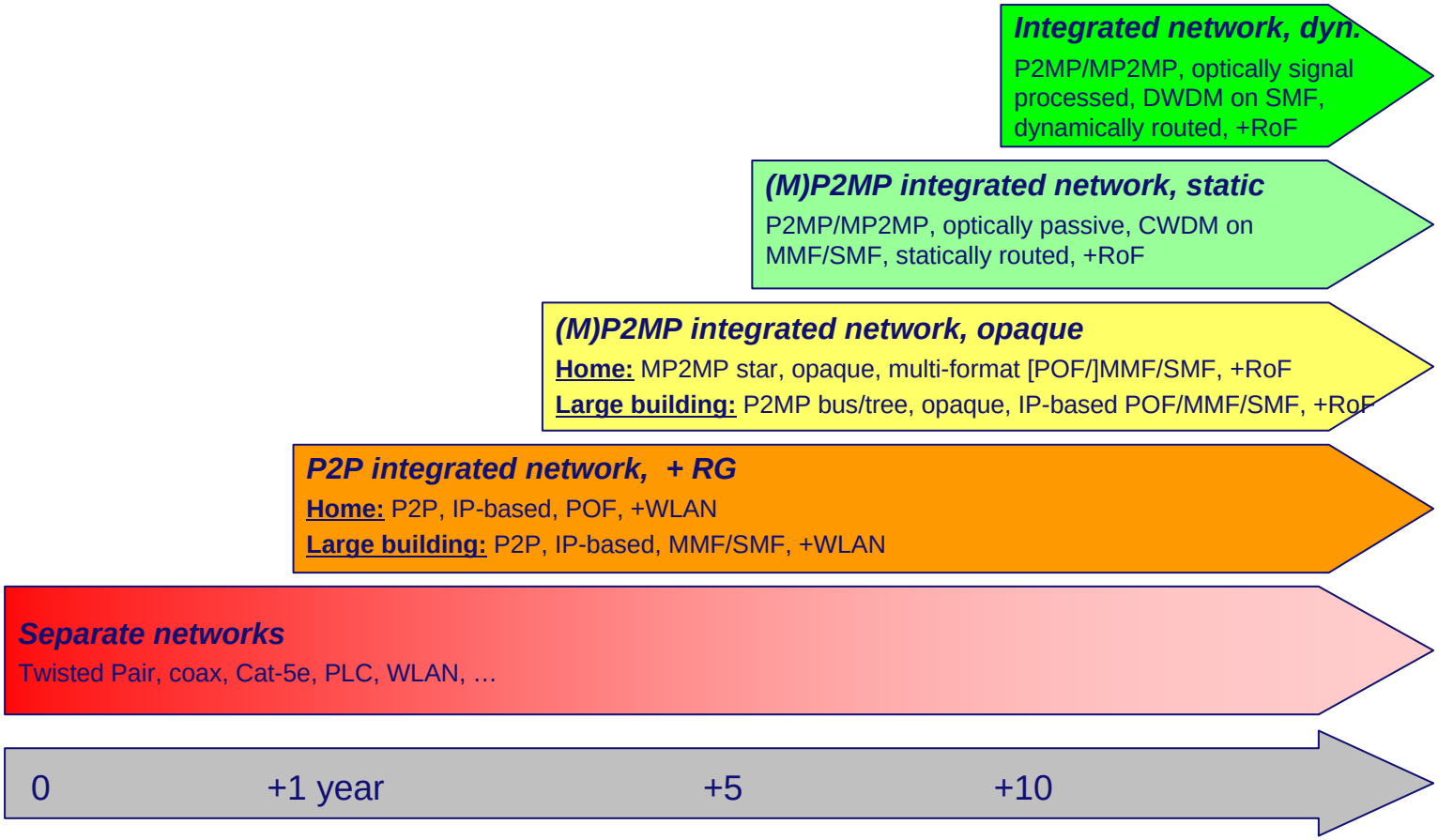
How real are POF networks?



First DIY Swedish POF installation in a house, summer 2010

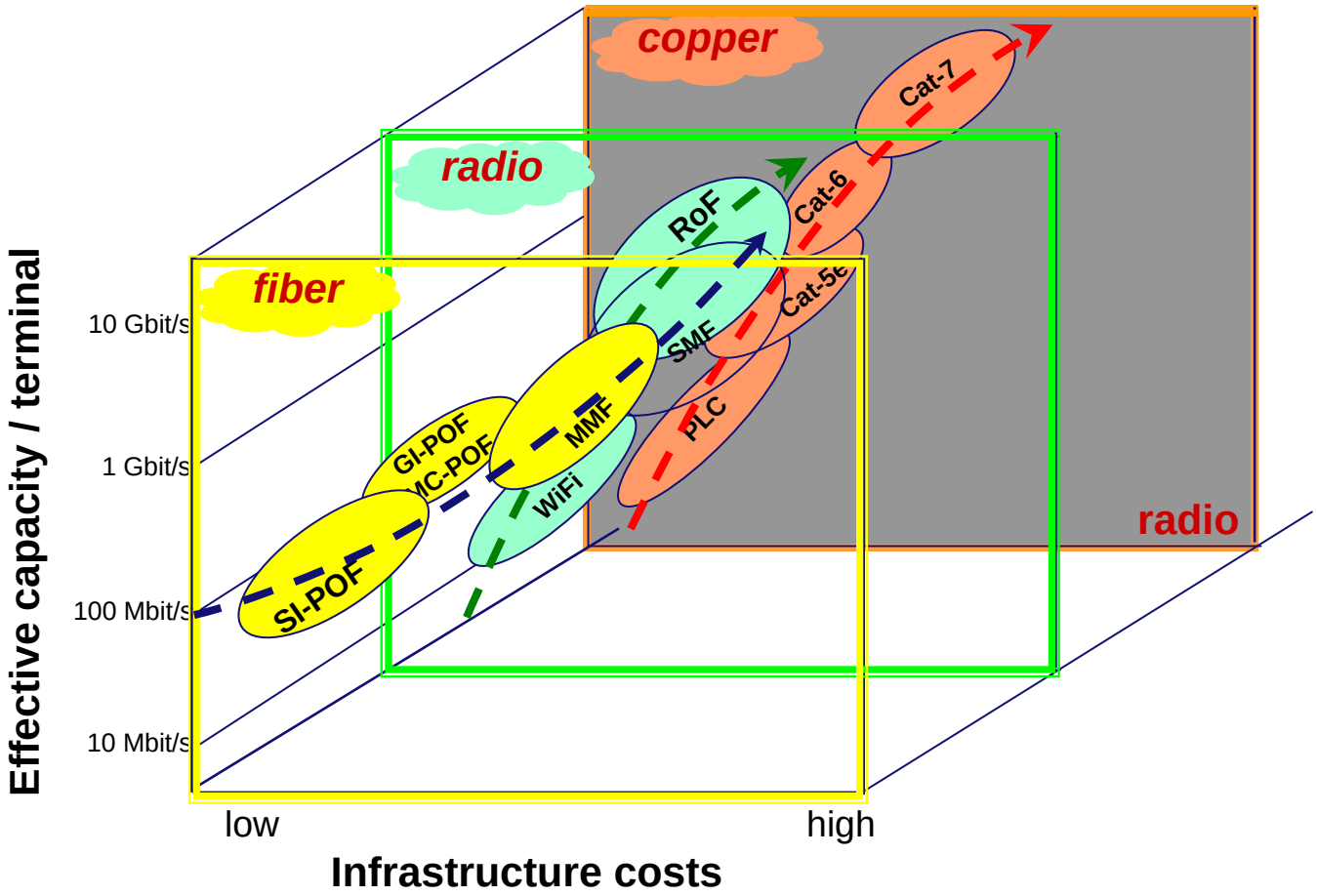
Source: ALPHA D0.5

Roadmap of wired in-building networks



→ fibre-based solutions will pave the evolution path of in-building networks

Choosing the wired network medium



When increasing capacity per terminal, network infrastructure costs grow

- super-linearly for copper and radio solutions
- sub-linearly for fibre solutions

Concluding remarks

- A single in-home fiber network can provide the universal backbone for delivery of wired and wireless services.
- Large-core POF is already today cost-competitive with Cat-5E and other cabling solutions, in particular when deploying duct sharing, and is quickly becoming the preferred solution for short-reach in-home links.
- Roadmap: growing needs for capacity, QoS diversity and flexibility require fibre solutions, evolving from P2P, to P2MP opaque, to P2MP all-optical from static to dynamic
- Network costs of fibre solutions increase less than linearly with capacity provided; those of copper and radio solutions more than linearly
- **In-building fibre solutions are more future-proof, more cost-efficient at higher data capacities, and more sustainable than copper and radio solutions.**

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