The new broadband world: back to circuits again?!
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Nico Baken
KPN Corporate Strategy & Innovation, Delft University of Technology, The Netherlands

Martijn van Riet, Joost Warners
TNO Information and Communication Technology, Delft, The Netherlands

Major trends in telecommunication

- An ever decreasing demand for real-time high QoS broadband Value Added Services due to the increasing economic and social impact of our sector, an accepted trend/fact worldwide

- Consumers/Users/Machines want to enjoy these services anytime, anywhere, preferably wireless

This faced and faces the telecommunication with an enormous challenge!

- In a world where bandwidth was scarce, the answer was and is to introduce efficient packet-switched networks …

- … which are intrinsically not suited to deliver high QoS

- … try to repair this with increasing complexity of the routing algorithms

- … and now we see the bandwidth cycle turning to abundance …

Question: are we making the right move or do we waste billions?

Future Architecture: The Telecom Mycelium
**a collection of fibre threads and fixed nerve nodes,
predominantly wirelessly connected to source and destination via T-mushrooms**
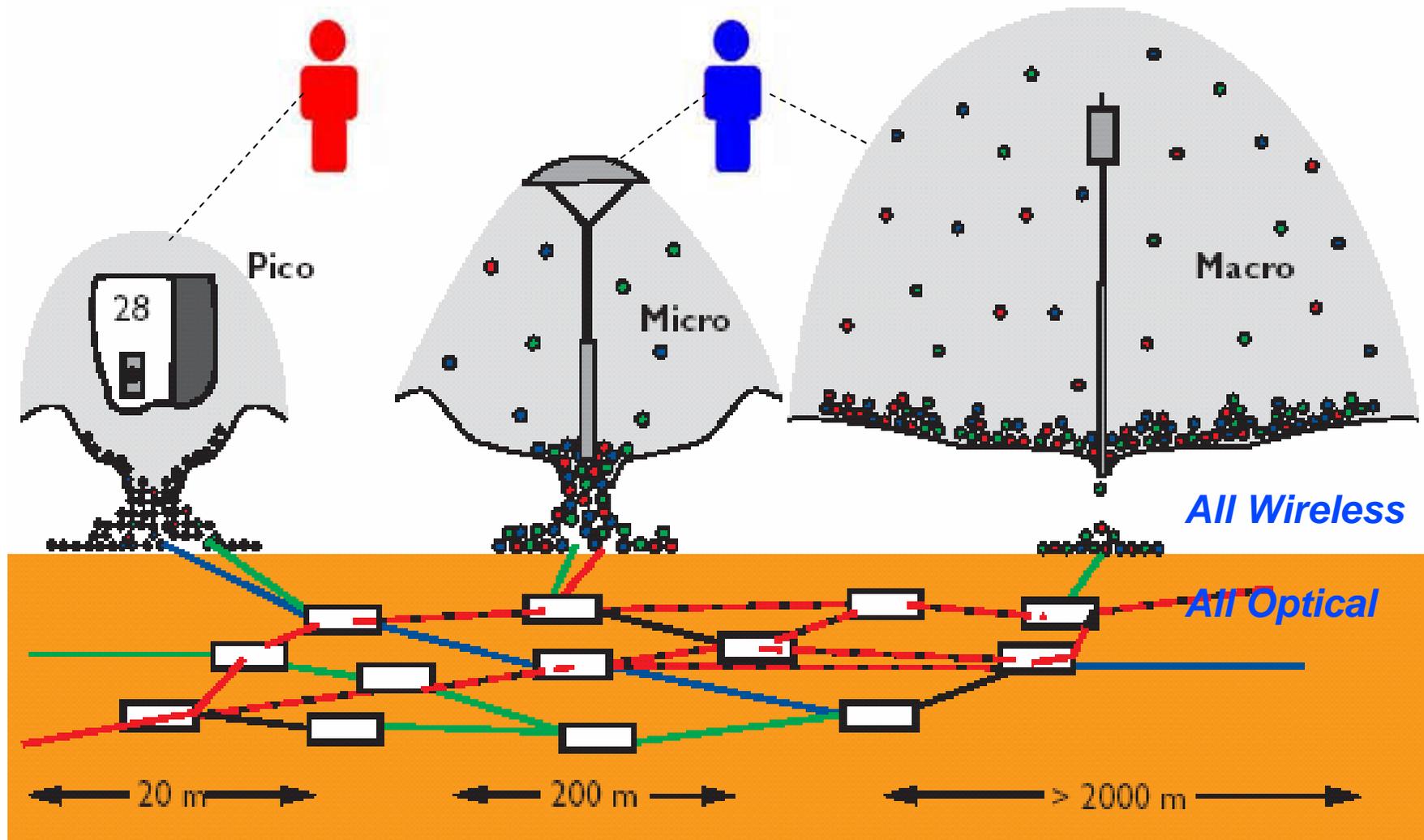
The telecom paradise: The fixed Telecom Mycelium

- The consumer has (wireless) access to all required services, via his/her *Personal Gateway*

    – Home Gateway

    – Vehicle Gateway

    – Street Gateway

- These access nodes are called

    the *nerve nodes* of the *Telecom Mycelium*

    – the fixed network is terminated by the gateways

    – using wireless techniques the access to the nerve nodes is realised, eg. ad hoc networking, mesh networks

VG

PG

HG

SG
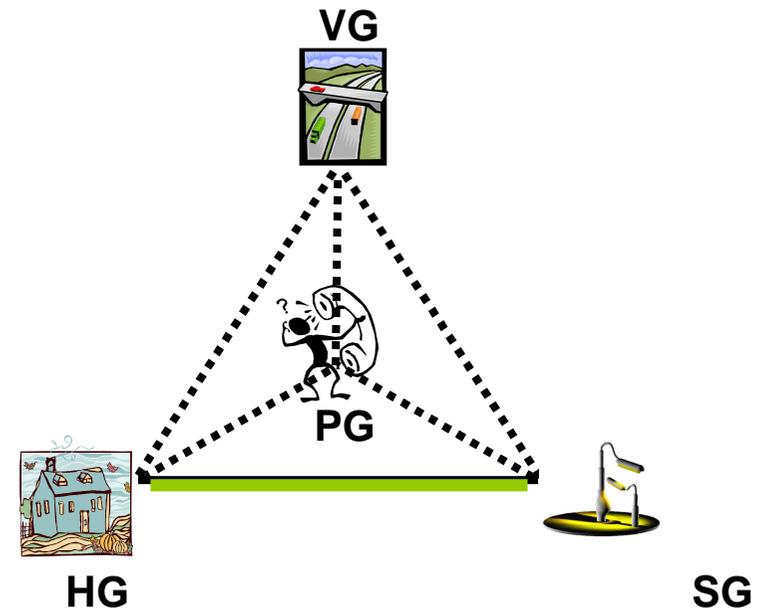
Question:

How do we mutually connect the nerve nodes,

providing the required bandwidth and QoS possibilities?

Back to circuits – optical circuits!

= λ-converter

- Imagine a hierarchical fiber topology:

- Adjacent rings are connected via a *λ-converter*
- Nerve nodes are mutually connected via all-optical circuits
  - guaranteeing high bandwidth and excellent QoS!
  - each NN can connect one or multiple radio-nodes/cells (pico, micro, macro), serving a host of users or directly connect the end-user

- *Is this possible?*
  - Let us specify the required functionality of the λ-converter
  - What are the (im-)possibilities
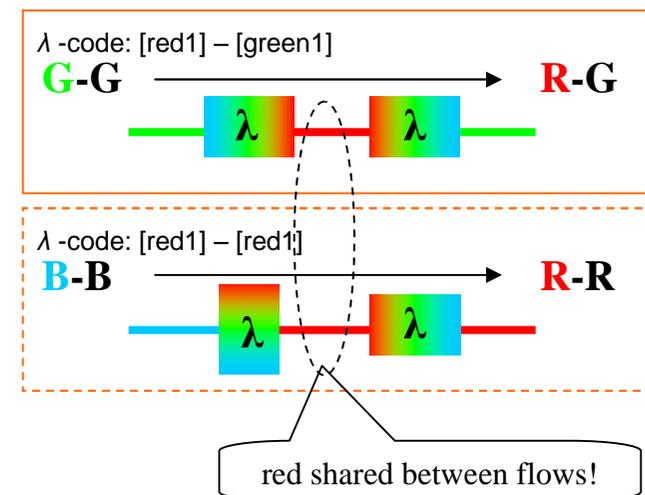   - in a quantitative sense
    - from a technical point of view
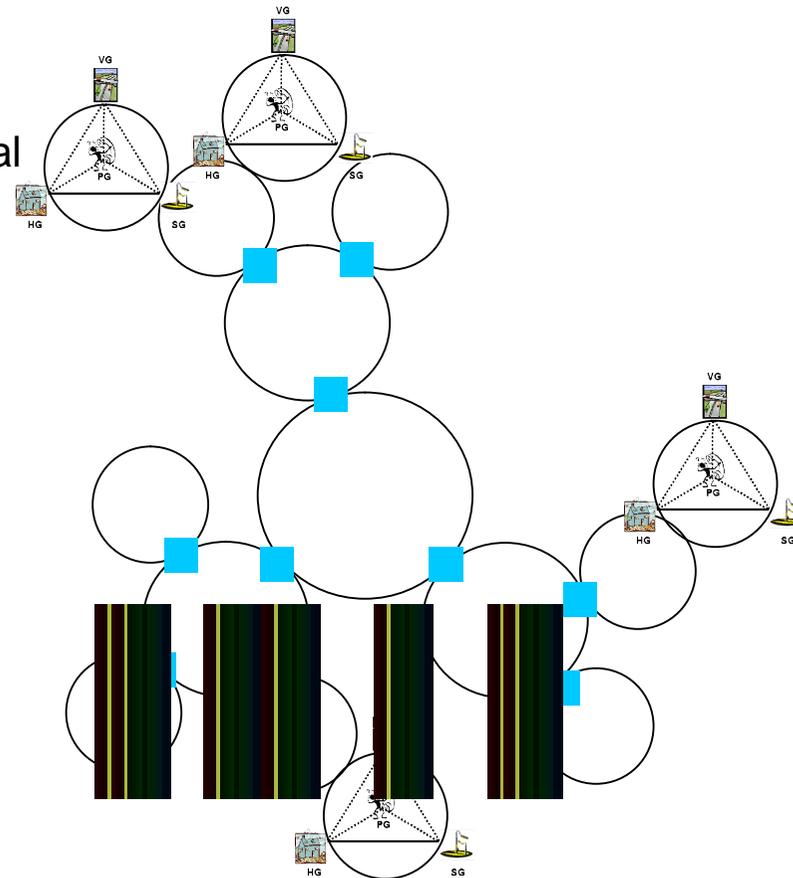
An all-optical solution - example
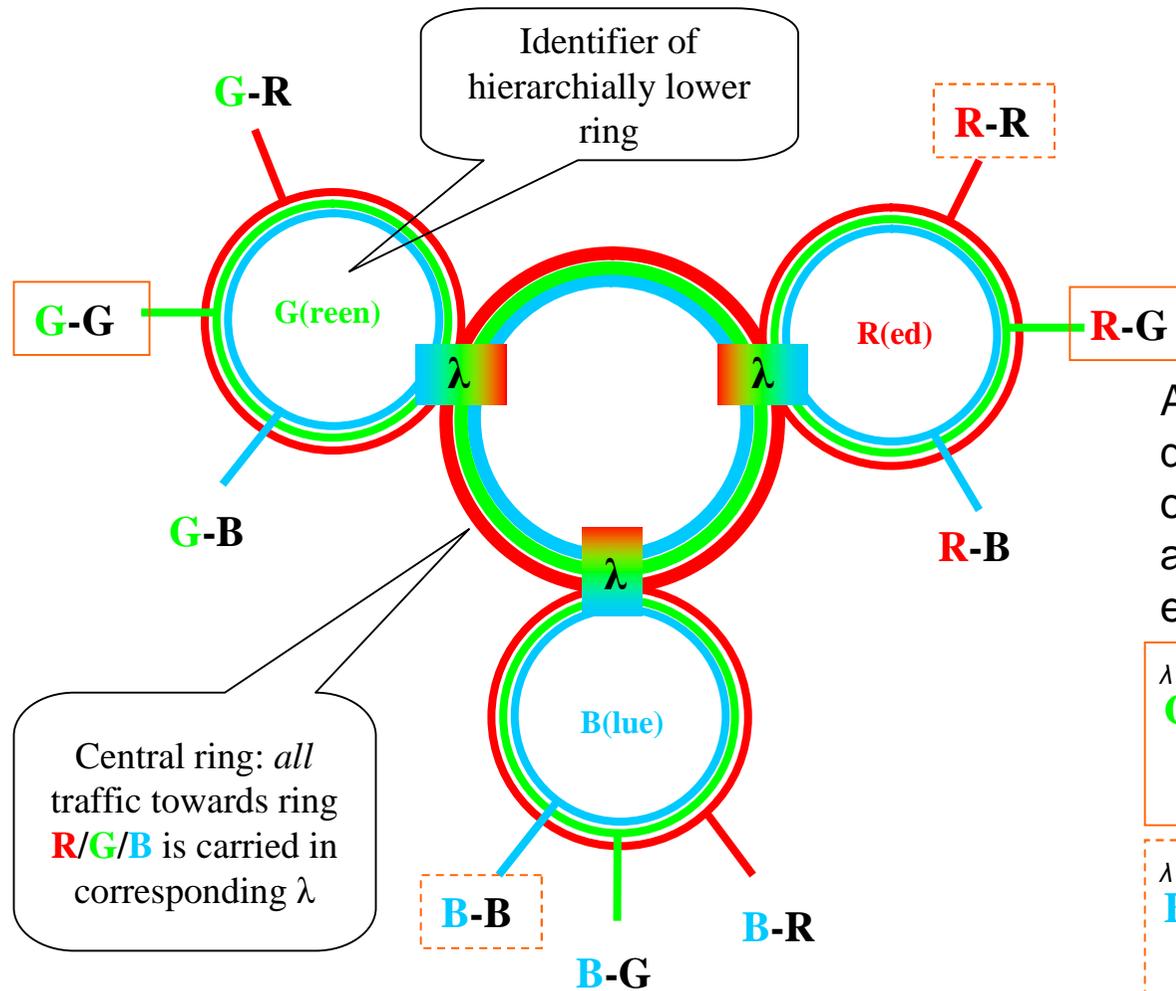
- # colours: $C = 3$
- level: $H = 2$
- # fibres/ring: $F = 1$
- nerve nodes are identified by their λ-**code**
- The number of access points is 9 (this is equal to C^H).

A route between A and B is defined by the concatenation of the inverted λ-code of A and the λ-code of B; examples:

λ -code: [red1] – [green1]

G-**G** $\longrightarrow$ **R**-**G**

λ -code: [red1] – [red1]

B-**B** $\longrightarrow$ **R**-**R**

red shared between flows!

G-R

Identifier of hierarchially lower ring

R-R

G-G

G(reen)

R(ed)

R-G

G-B

R-B

Central ring: *all* traffic towards ring **R**/**G**/**B** is carried in corresponding λ

B(lue)

B-B

B-R

B-G

# An all-optical solution – more formal

- Definitions:

  - # colours/lambdas per fibre: C

  - # fibres per ring: F

  - depth of hierarchy: H

  - A λ-**code** is a sequence of lambda-fibre combinations of length H

    - A λ-**code** serves a unique identifier of an access point

- The number of *unique* λ-codes equals $M = (C \times F)^H$

- This can be refined to take into account physical restrictions on the hierarchical network

  - In a "reasonable" hierarchical network of depth 5, with 64 lambdas per fibre, and 96 fibres per ring, the number of unique λ-codes is around 12.5 million.

  - Implying a grid of microcells of 100x100m^2 in rural and 30x30m^2 in urban areas for the Netherlands

- … but what does this require from the λ-converter?
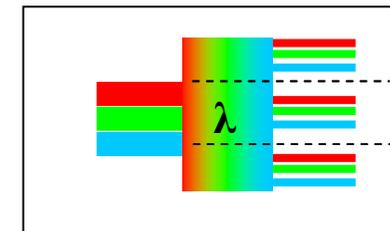
Implications / Requirements
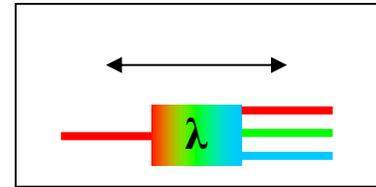

Implication / Requirement #1:

- The λ-converter must be able to

  – convert an incoming lambda into several outgoing lambdas

  (de-multiplexing)

  – convert several incoming lambdas into one outgoing lambda
  (multiplexing)
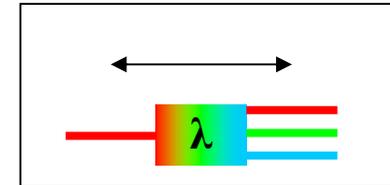
Implication / Requirement #2:

- The capacity required in the higher hierarchical rings must be shared by an increasingly large number of nerve nodes

  – Overbooking/Statistical multiplexing cannot be profited from at the higher hierarchical levels.

  – Basically, the central ring must be able to carry the sum of the access speeds of all nerve nodes!
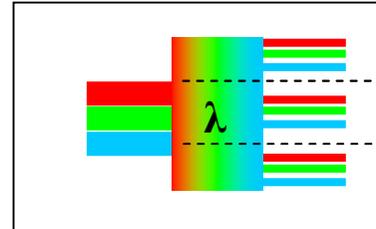
Implication #1 - remarks

- This multiplexing and demultiplexing has to be performed in the time domain.

    – (λ *conversion* is then essentially no longer necessary)

- This requires
  1) Burst transmission at 10 Gb/s, with burst lengths in the µs-ms scale,
  2) Time domain multiplexing of those bursts, and
  3) Dynamic buffering for burst synchronisation

- None of these functions are currently commercially available in the optical domain.
  Expert analysis is needed to evaluate their potential availability in the future

Implication #2 - remarks

- Required capacity in the central ring (hierarchically highest ring):

  Example

    - To cover a country like the Netherlands (40.000 square kms), approx. 12.5 million nerve nodes suffice (100 – 1000 nerves nodes per sq. km)

    - Each nerve nodes has an access speed of 10 Mbps

    - In the central ring, $12.5 \times 10^6 \times 10$ Mbps = 125 Tbps is required

    - Feasible configuration:

        - ~ 100 fibres (10^2)

        - ~ 100 λs per fibre (10^2)

        - ~ 10 Gbps per λ (10^1)

        $\rightarrow 10^5$ Gbps = 100 Tbps

    - The (theoretical) capacity of hierarchically lower rings is typically of a similar order, but

        - due to the lack of statistical multiplexing and overbooking effects these rings will have a (very) low fill grade

Implication #2 - remarks
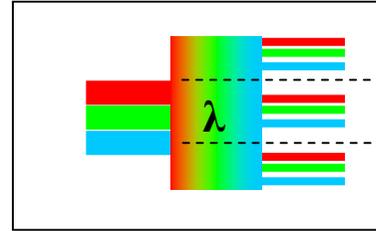
- Proper operation over multiple hierarchical level requires either
  - Customer Premises Equipment able to operate at peak line speeds matching those of the highest hierarchical levels, or
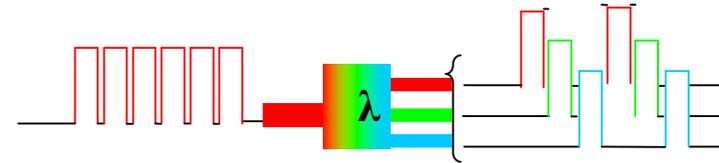
  - Time-compression / -expansion functionalities in the core network, to translate streams of short high-speed bursts into a more continuous bitstream at lower bitrates.
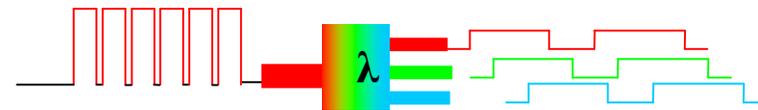
- To our knowledge, neither of these functions are currently commercially available in the optical domain. But development is ongoing!

The all-optical solution – concluding

- The all-optical scenario has some serious technical challenges, related to the integration of many hierarchical levels in one optical domain.

- The all-optical solution is the key to the new, dreamt-of, world of telecommunication: broadband access anywhere, anytime to high QoS services!

- Ultimate Fixed Mobile convergence!

- Literally transparant and simple architecture!

- It is therefore logical and entirely worthwhile to study our suggestion in depth

- In fact, our concept can be envisaged as the next step of the Negroponte switch … how about the *Baken switch*