Design of Broadband Access Networks

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  xDSL, CATV, PLC, Public mobile networks, WiMax, WLAN, Satellite, ..
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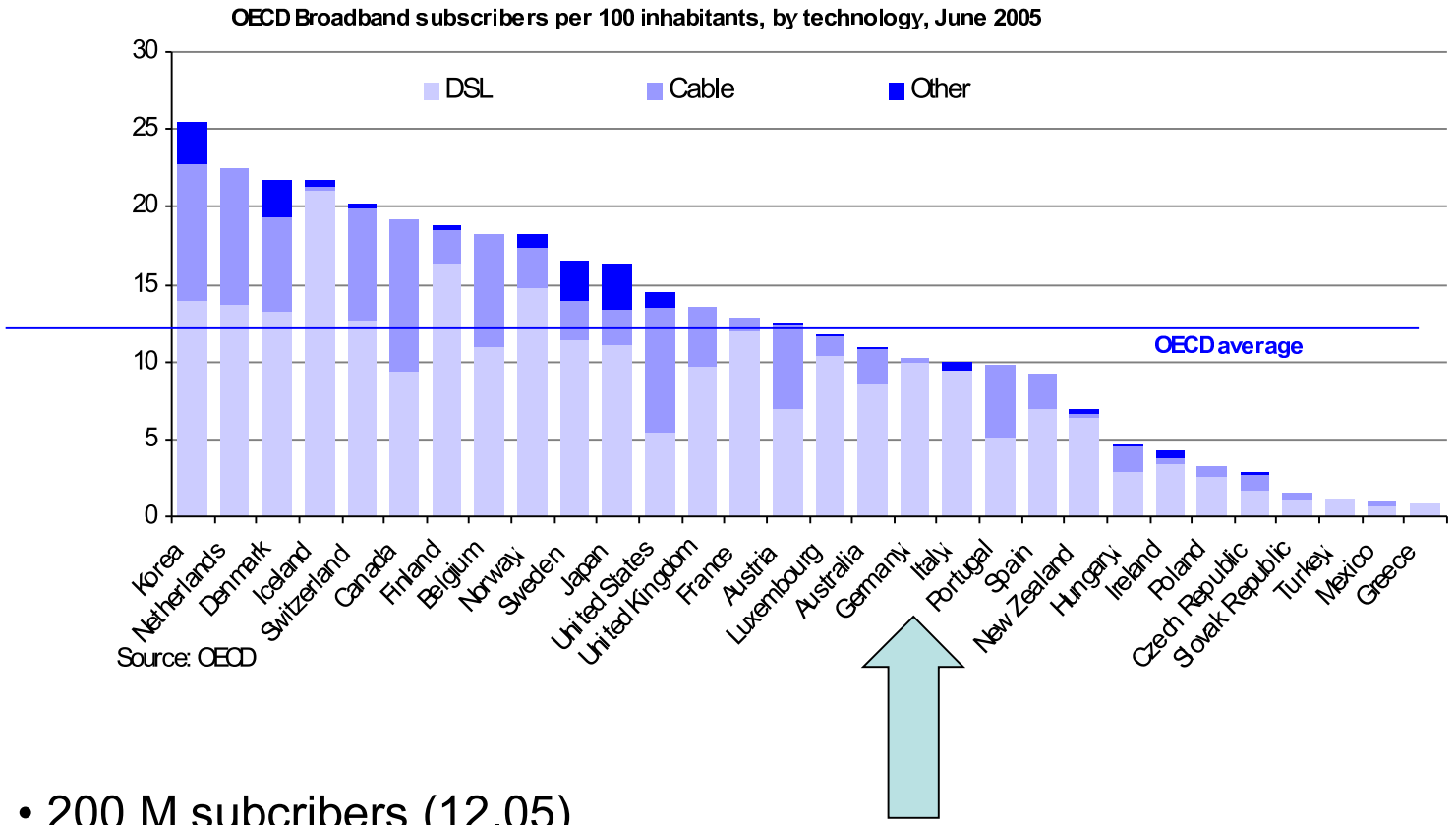
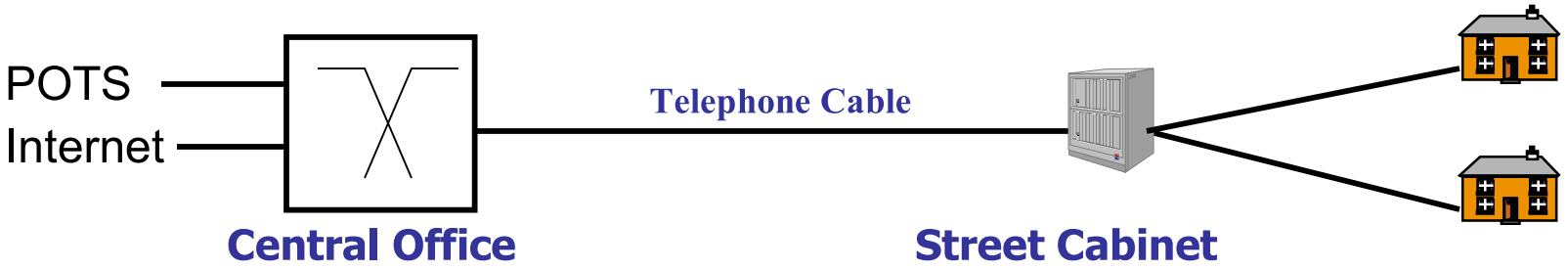
Broadband Access Statistics



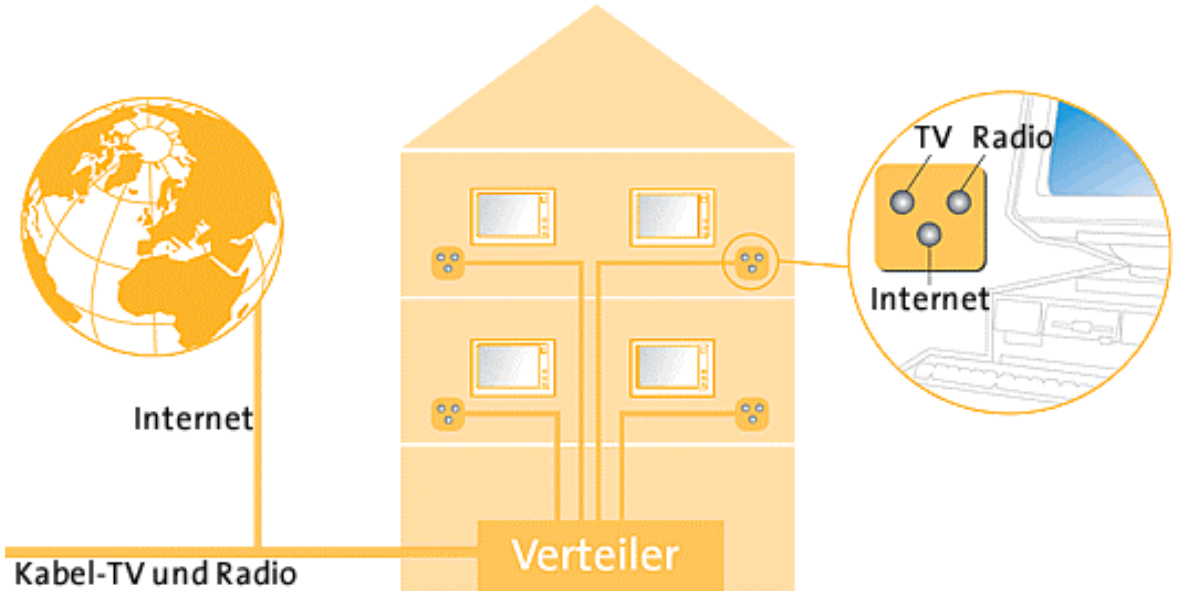
- 200 M subcribers (12.05)
- D: BB density below OECD average
- D: Cable use neglectable
- other technologies: few customers

xDSL



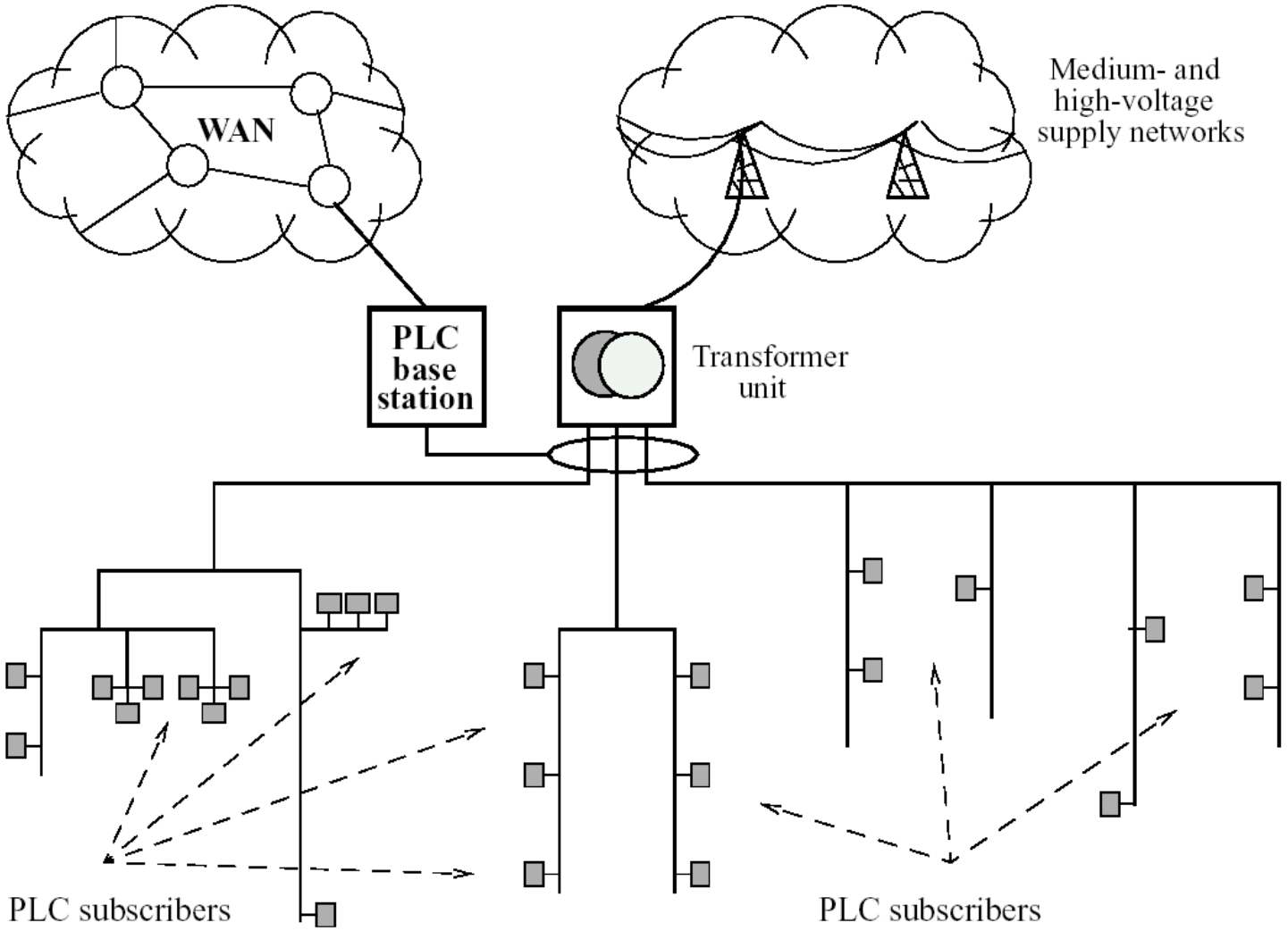
- Medium: POTS access line
  - Typ. use: ADSL
  - Data rate: 0.784..**2**..16 Mbit/s, 50 Mbit/s soon
  - Covered distance: 0.3..5 km
- Currently. 11 M subscribers (D),
  - 25 % of households, Telekom: 95% market share
  - No. 13 (Europe), no. 18 worldwide
  - World: 140 M subscribers, 61% share of BB market

CATV



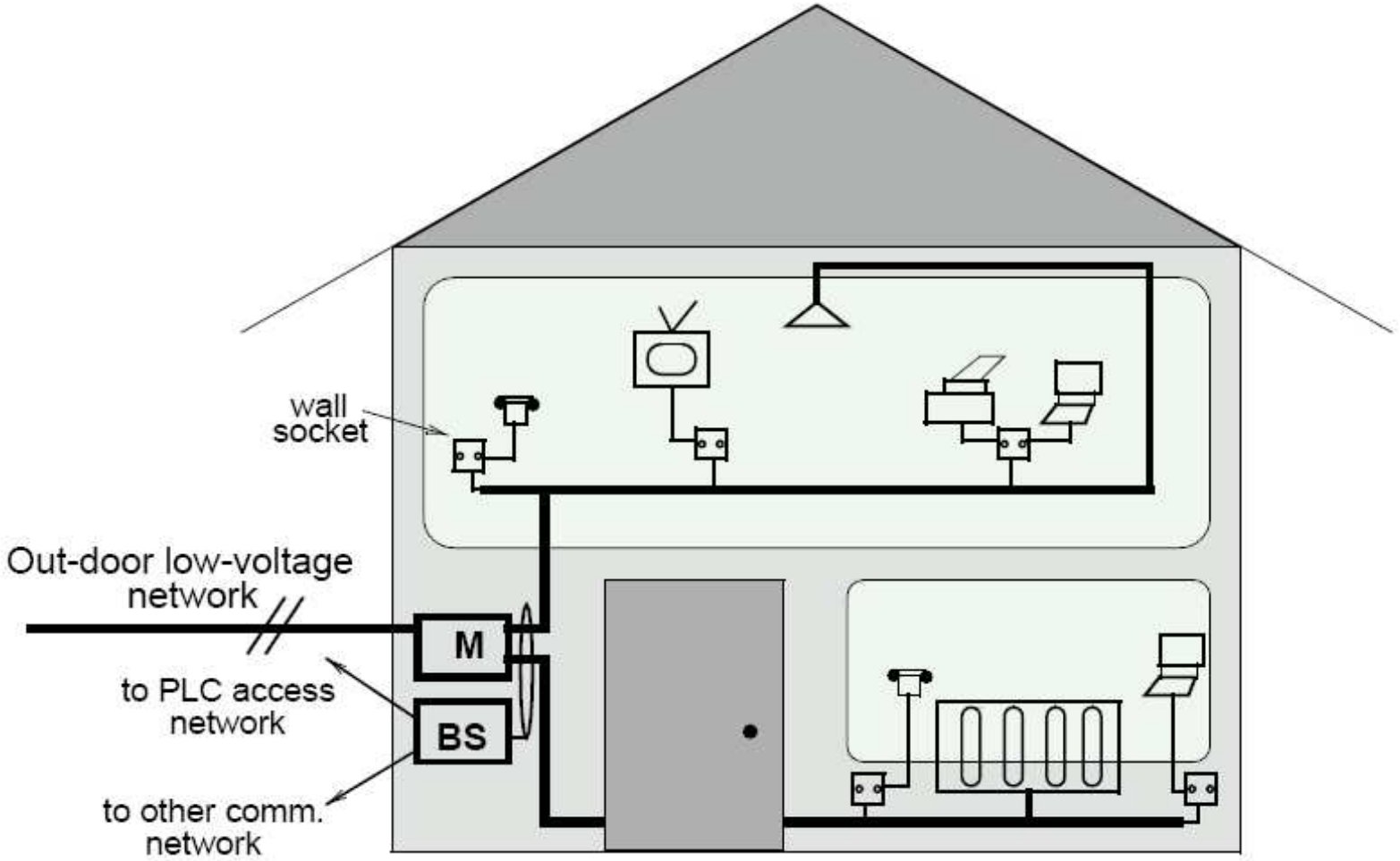
- Upgrade of CATV distribution network – setup of backward channel
- Wall outlet: new 3rd plug: Internet
- Data rate: 1..**2**..8 Mbit/s downstream
- Shared medium
- Status: commercial, 32% of BB world market

Power Line Communications



In-Home PLC

Home-Plug Standard 1.0 / 2.0



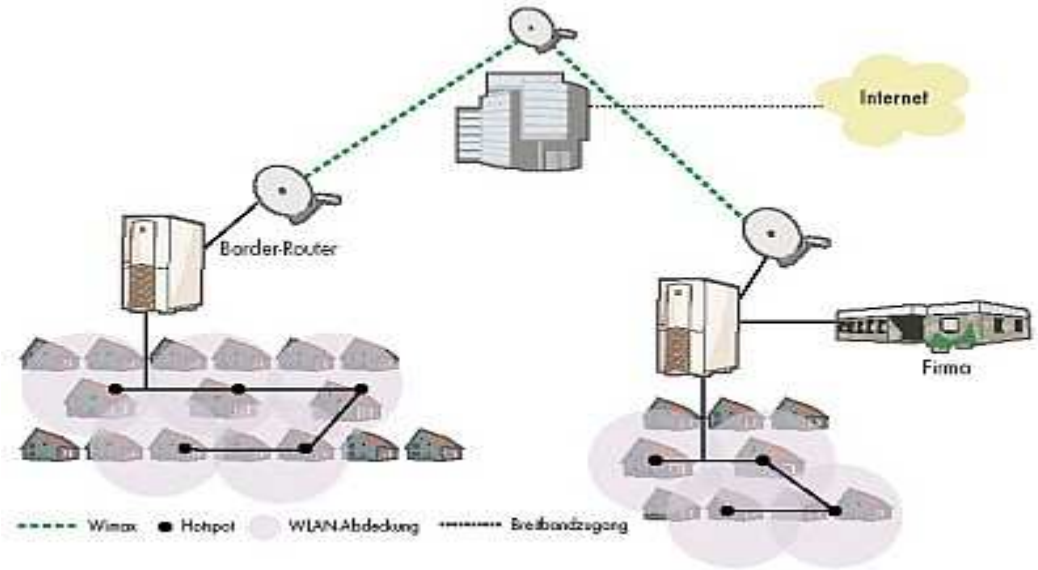
Access PLC ..

- Gross data rate: 200 Mbit/s @ 500 m
- Standard defined by OPERA consortium
- Shared medium
- Dynamic bandwidth allocation possible
- Problems:
  - Power line is a „bad“ transmission medium
  - Electro-magnetic compatibility (EMC)
- Status: Field trials
  (2 Mbit/s systems: commercial)

Mobile Networks

- UMTS: 384/64 kbit/s
  - Mobile use (roaming & handover possible)
  - Shared bandwidth (cell capacity 2 Mbit/s)
  - Latency: approx. 300 ms
- New modulation schemes
  - HSDPA: **1.8**..3.6..14.4 Mbit/s (cell capacity 14.4 Mbit/s)
  - HSUPA: **0.384**..1.4..5.8 Mbit/s
  - Latency: approx. 100 ms
  - Status: commercial start 2006
  - High tariffs

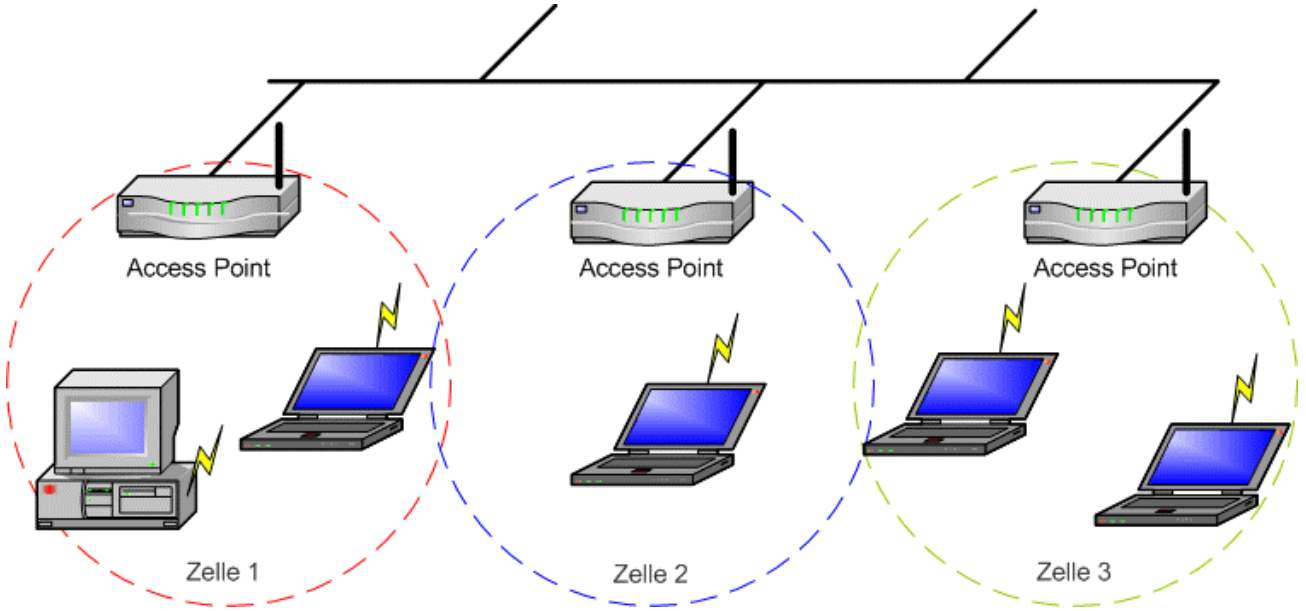
WiMax



Worldwide Interoperability for Microwave Access (IEEE 802.16x)

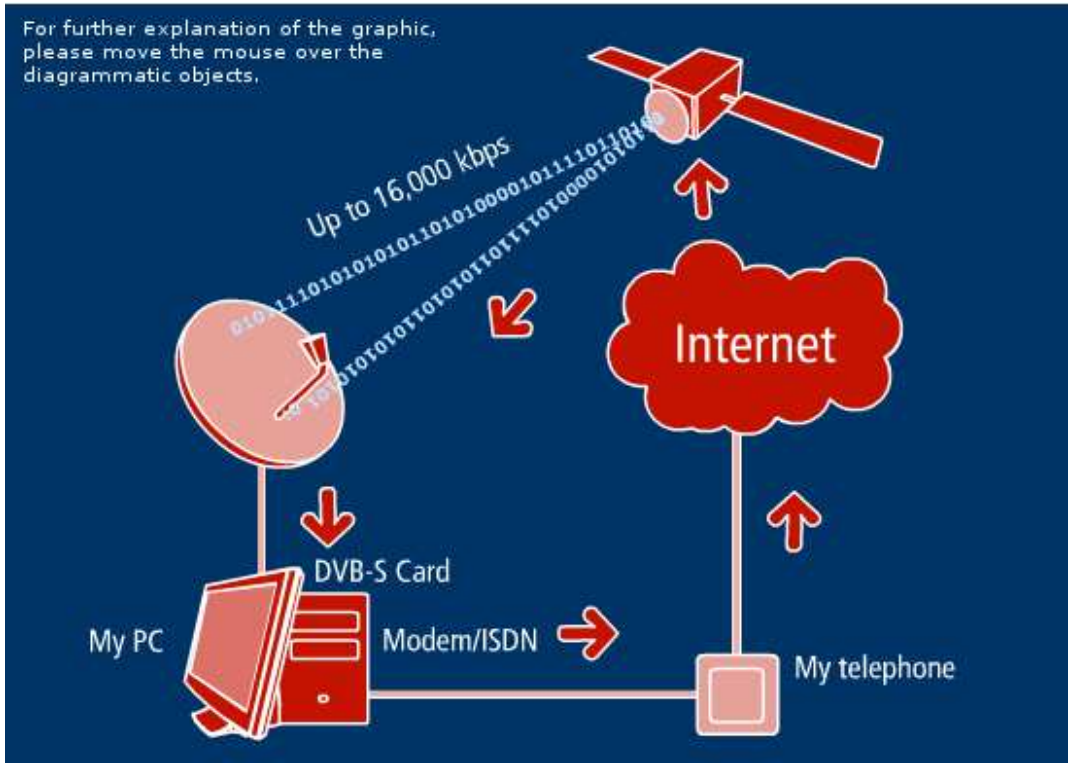
- Gross data rate up to 108 Mbit/s, DSLonAir: 1.5 Mbit/s / subscr.
- Coverage: up to 50 km
- Use: fixed wireless, mobility planned 802.16e
- Shared medium
- QoS for voice (real-time services)
- Status: commercial installations just started

WLAN



- Standard: IEEE 802.11x
- Gross data rate 11..**54**..108..320 Mbit/s
- Shared medium
- Limited coverage: 30..300 m
- No seamless handover
- Status: commercial (mass market)

Satellite

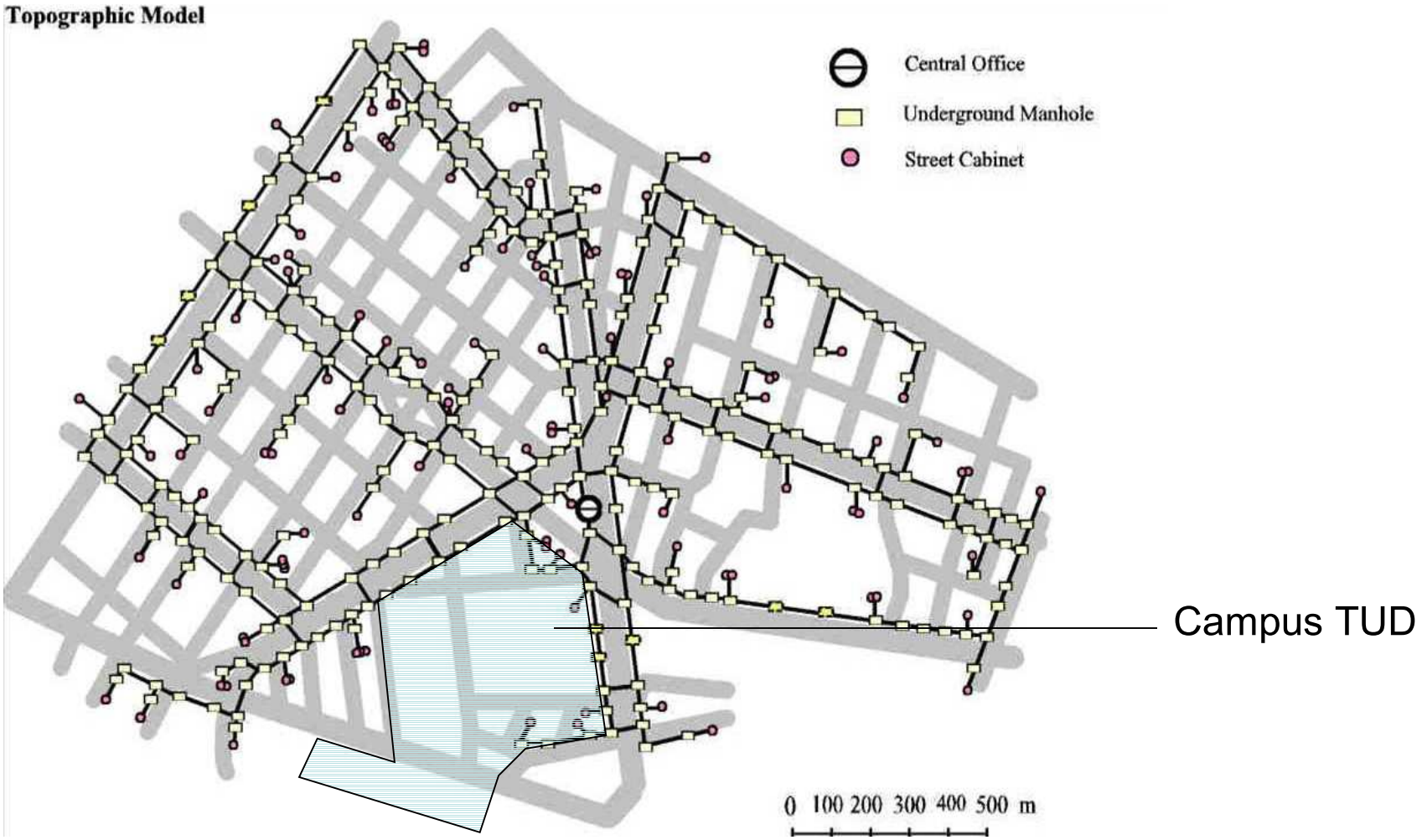


- Downlink: Satellite, uplink via PSTN, asymmetric: 16 Mbit/s / 64 kbit/s
- Downlink: shared medium, many customers!
- Latency: 500 .. 1000 ms
- Status: commercial (Teles SkyDSL)

General Remarks

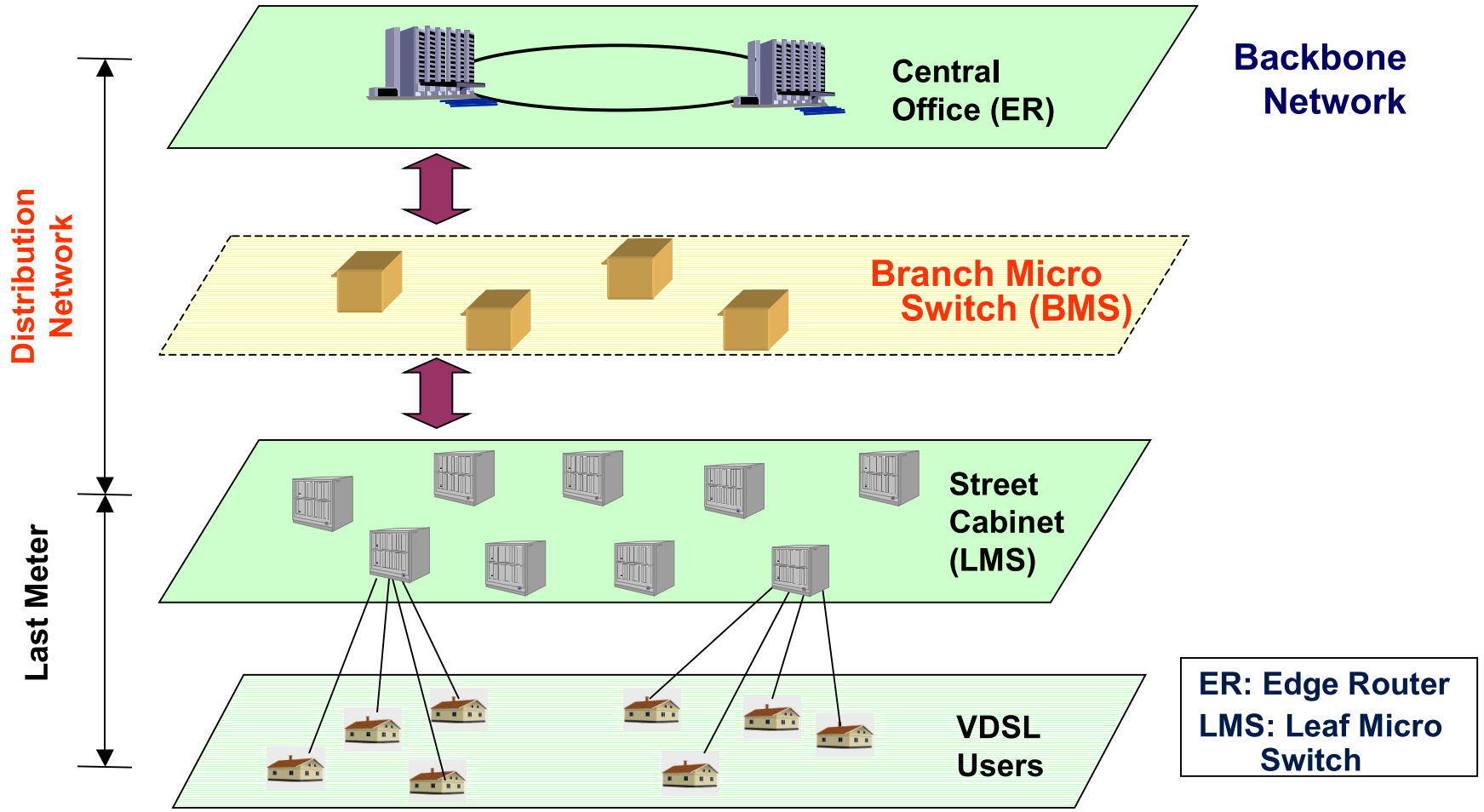
- Physical layer
  - OFDM: major leap forward ..
    - Robustness against noise, fading, disturbances
    - Adaptation to varying channel qualities
    - Up to 1536 carriers (PLC)
  - Next improvement steps: MIMO, UWB
  - EMC problems to be resolved!
- FTTH still to be deployed?
- Current market share:
  61% DSL, 32% cable, 7% other

Cable Network Design Challenges



Scarcely meshed network, few alternate routes, availability

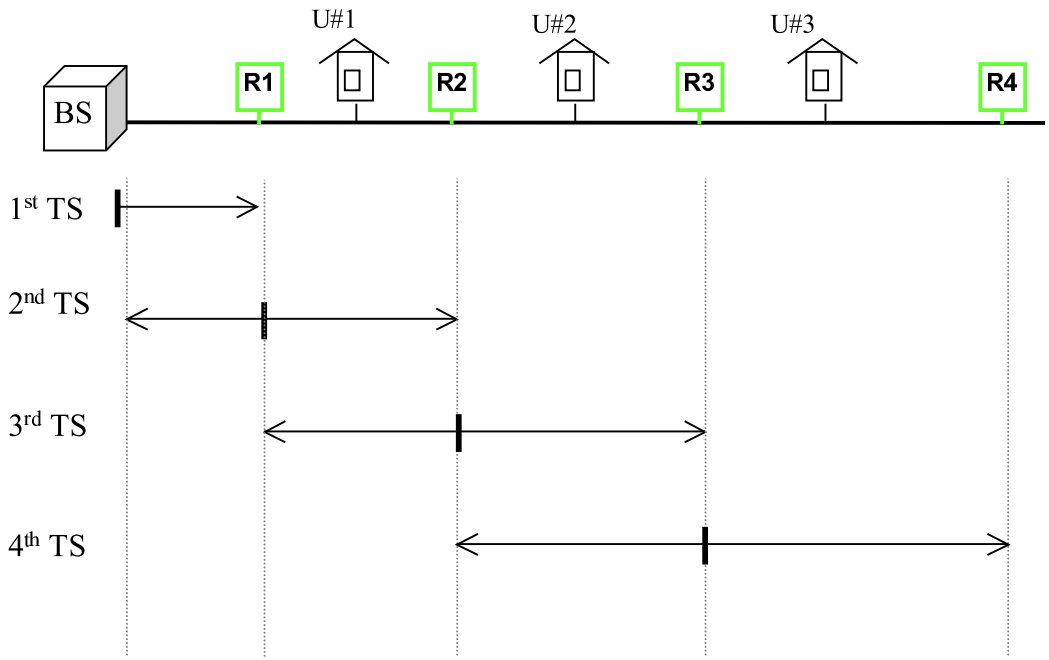
Design Challenges ..



Limited coverage for VDSL, connectivity

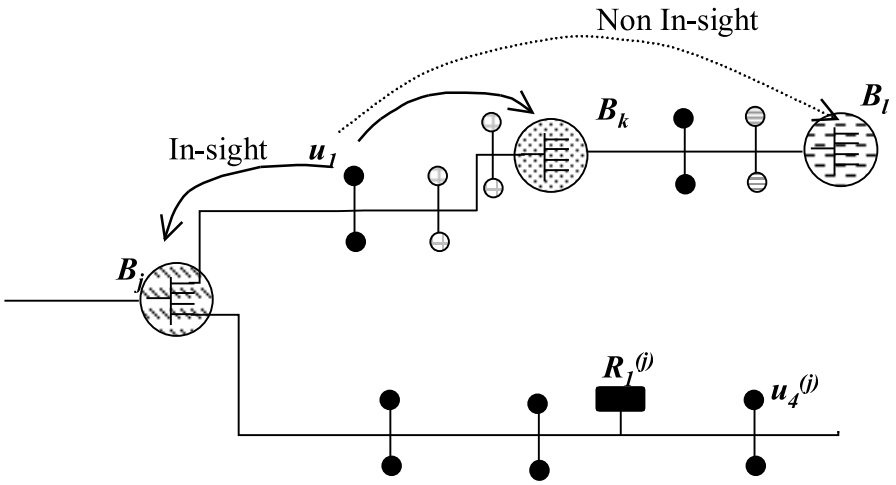
PLC Network Characteristics

- Limited coverage → repeaters
- Signal propagation in two directions → bandwidth reduction



PLC Network Characteristics ...

OFDM channel reuse distance = 2



Example: PLC Network Design

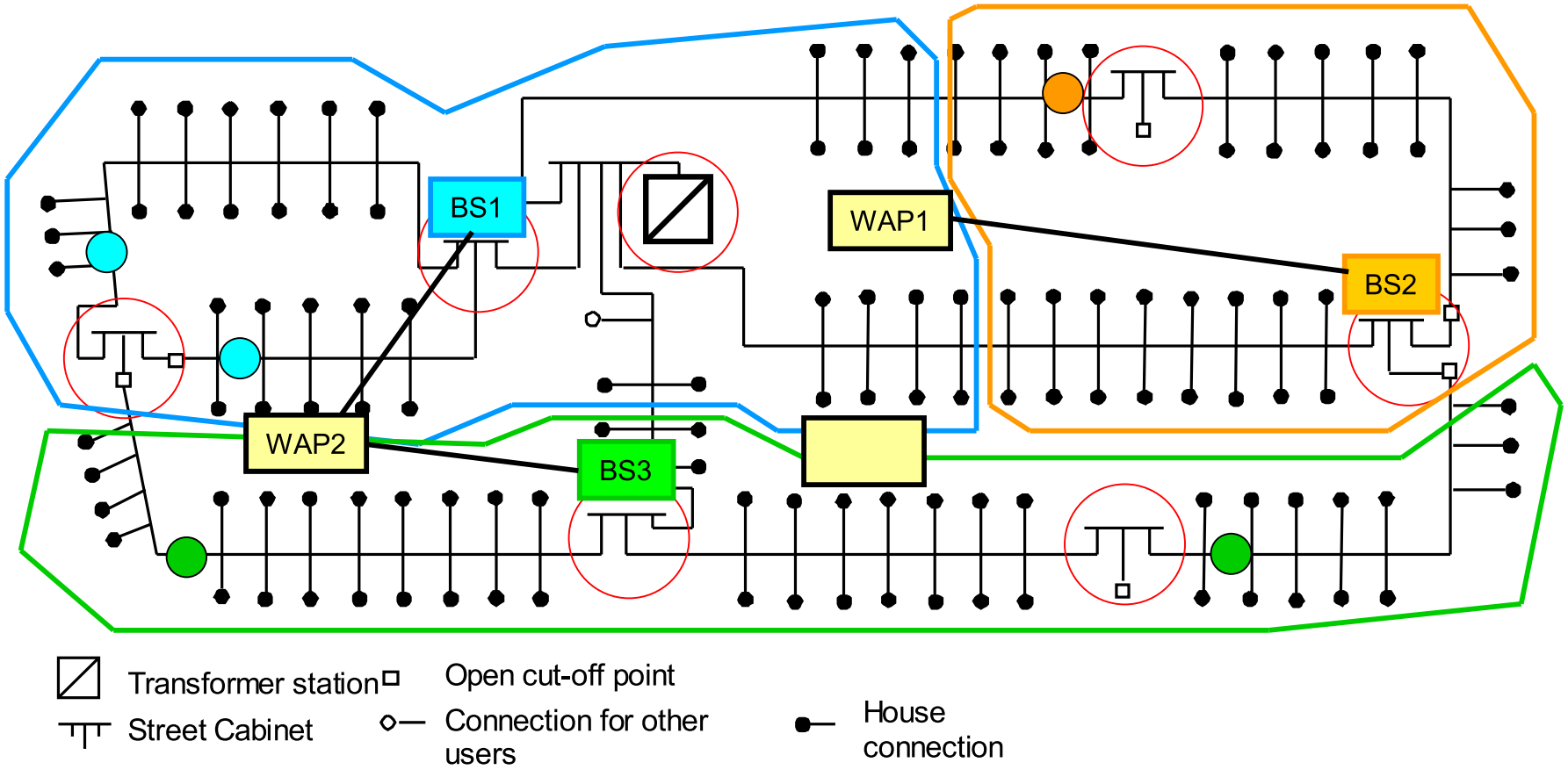
Objectives

- Minimize costs
- Maximize goodput
- Minimize transfer delay
- Boundary conditions:
  - QoS guarantees per user
  - .. per service

Planning Steps

- BS placement & clustering
- Repeater placement
- WAN gateway placement
- Channel allocation

Planning Steps



Channel Allocation Procedure

Given:	•The neighbourhood matrix M_{Nei} •The interference distance matrix M_{ID} •Set of PLC channels F_S •Users traffic demand •Parameters of the impulse noise model
Tasks:	•Allocate to each cell j a sub-set $F^{(j)}_{alloc}$, with $F^{(j)}_{alloc} \subseteq F_S$
Objectives:	•maximize: the resource reuse, the network availability •minimize: interference level in the PLC site
Constrained by:	•the set F_S •users traffic demand •interference distance matrix •neighbourhood matrix

Result: channel allocation matrix

$$M_{CA} = \begin{bmatrix} a_{1,1} & \Lambda & a_{1,F} \\ \mathrm{M} \;\; \mathrm{O} & & \mathrm{M} \\ a_{j,1} & a_{j,f} & \mathrm{M} \\ \mathrm{M} & \mathrm{O} & \mathrm{M} \\ a_{B,1} & \Lambda & a_{B,F} \end{bmatrix}$$

Optimization Methods

Enumeration ⇒ Comp. complexity

⇒ Heuristics (strategy)

Algorithms

- Evolutionary methods
  - Genetic Algorithms
  - Fuzzy inference
  - Particle Swarm Optimization
- Local based search methods
  - Simulated Annealing
  - Tabu Search
  - Hill Climbing

Problems

Convergence

- many iterations in case of small minima

Conflicting Objectives

- costs vs QoS
- resource reuse vs interference,
- costs vs reliability..

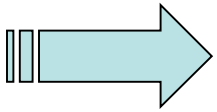
Single Objective Opt.

Standard approach:

- weighting factors in objective function

$$\begin{aligned} &\text{maximize} && y = f(\mathbf{x}) = w_1.f_1(\mathbf{x}) + w_2.f_2(\mathbf{x}) + ... + w_k.f_k(\mathbf{x}) \\ &\textit{subject to} && \mathbf{x} \in \Omega_f \end{aligned}$$

- How to choose the factors w?



Single-Objective Optimization (SOO)

Multi-Objective Optimization

Based on the principle of dominance

•Goal: Building a Pareto front

•Example of 2-dim MOO-Space (Cost, Delay)

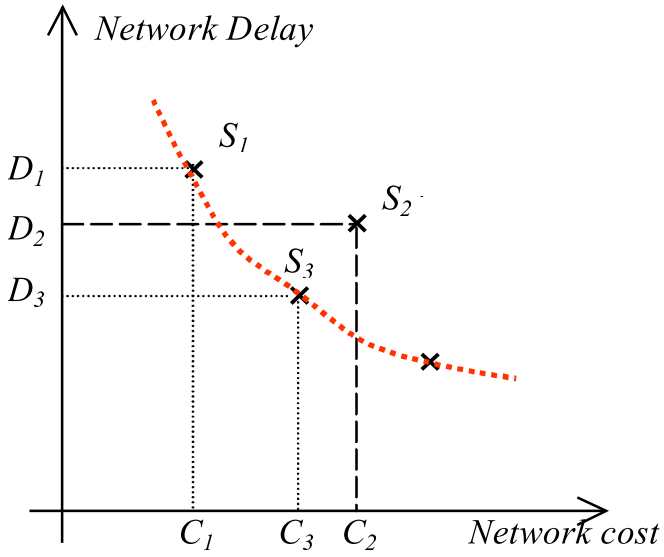
•For each sampled Si → (Ci,Di)

–Because $C_3 < C_2$ **and** $D_3 < D_2$, S_3 dominates S_2

→then keep S_3 and drop S_2

–$C_1 < C_3$ **but** $D_1 > D_3$, S_1 and S_2 are not comparable

→then keep S_1 and S_2



•S_1 and S_2 ∈Pareto front

•Pareto front := set of the best encountered (not-comparable) solutions

Example

- Two comparison keys:
  - Global comparison: cardinality, covered surface, etc.→more general
  - Restricted comparison: cutting the dominated hyperplanes →practical
- Visualization: possible only in case of 2Dim