

NRENs, connectivity & power

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A rather improvised talk on ...

- **Wireless connectivity** for NRENs, Campus, organizations
 - Key elements
 - Long distance links (if interesting?)
- **Power** for networks
- Plenty of time to **discuss, ask, go into details**

About myself

- Physicist turned IT/networking guy
- 15 years wireless experience
- 10 years capacity building / training in Africa/Asia
- Proudly and happily with
<http://nsrc.org> - the Network Startup Resource Center
<http://itu.dk> - IT University of Copenhagen, Denmark

Wireless at home (IT University)



Power at home (IT University)



- Working towards a university free from fossil energy by the year 2020 – and connecting globally:

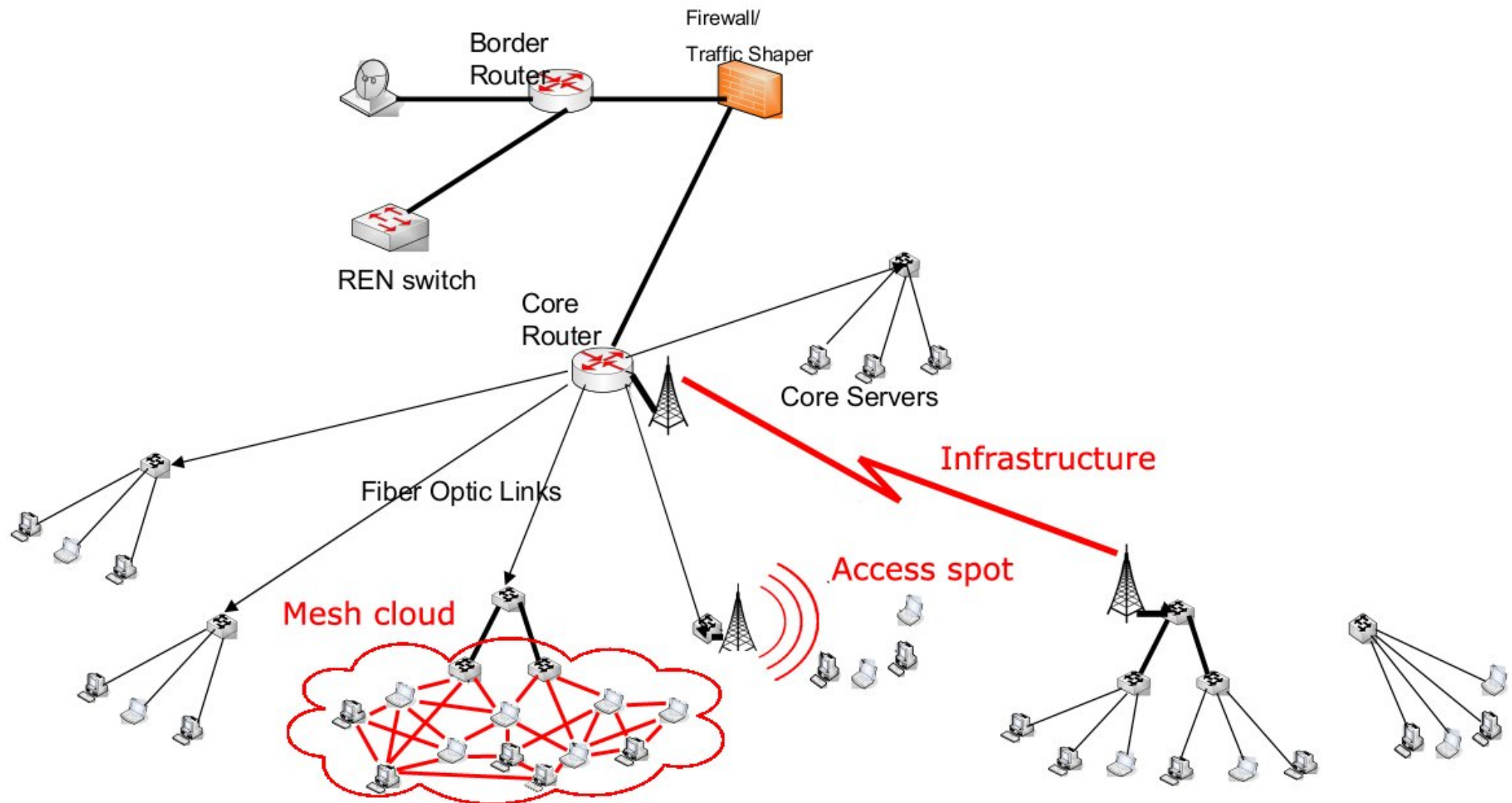
<http://energyfutures.itu.dk>

Part 1:

Wireless connectivity

- First rule for wireless connectivity:
wherever you can, **go wired** - do fiber and cable
- **Integrate wired and wireless networks:** one network architecture

Roles of wireless elements



State of the wireless art

What can we do today?

- a 10 km link with 1 Mbps for < \$100
- a 1 km link with 10 Mbps for \$100
- a 10 km link with 100 Mbps for \$200
- a 1 km link with 1 Gbps for \$300
- an access network for 1000 - 5000 concurrent users for \$5000 - \$10000

Some essential elements

- Making a **site survey**
- Being clear about **requirements**
- **Choice of frequencies**
- **Reach and coverage**
 - Link budget
 - Coverage planning
- **Antennas**
- **IP Planning**
- **SSID design**
- **Access & Authentication**

Site Survey

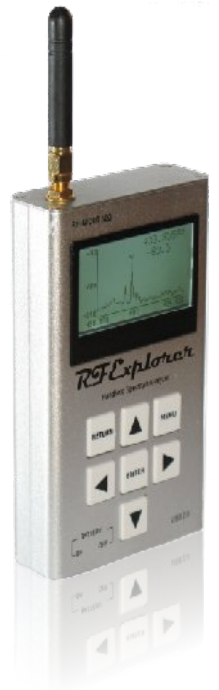
- No matter what network you are building, core infrastructure or edge access, a **site survey** is mandatory
- Results of the site survey are the basis for your technology and process decisions

Site Survey

- **A site survey includes**
 - **Spectrum analysis**, wireless scan – check for conflicts and interference
 - **GPS coordinates**
 - **Power/Electricity** conditions
 - **Wired network** conditions
 - **Environmental** conditions
 - **Social / human factors** ... who are my neighbours?
 - **Documentation of everything!**

Site Survey - Tools

- Inexpensive **spectrum analyzers**
 - WiSpy <http://www.metageek.net/>
 - AirView <http://www.ubnt.com/airview>
 - RF Explorer <http://micro.arochoh.com/>
- Software tools e.g.
 - kismet / Netstumbler
 - nm-tool
- Even an Android phone can do something:
e.g. WiFi Analyzer



Site Survey

- Think holistic!
Networking is
more than pinging!

Primary School

Coordinates

S238 40.5 E3239 04.7

IP number

10.1.1.20

Comments & Pictures



Requirements

- **What do you want to do?**
 - **How far, how fast, how many, ...?**
 - A Wireless Sensor Network might need just a few bytes from many miles away
- while a campus backbone link might need 1 Gbps over 500 meters
- and an access network for users might need 10 Mbps to each of its users

Choosing frequencies

- **ISM bands e.g. at**
433 MHz, 868/900 MHz, 2.4 GHz, 5.7 GHz
- **Some rules of thumb**
 - higher frequency, higher data rate
 - higher frequency, shorter reach
 - lower frequency, better penetration (through objects, environment)
- **Interference, coexistence, legal aspects?**

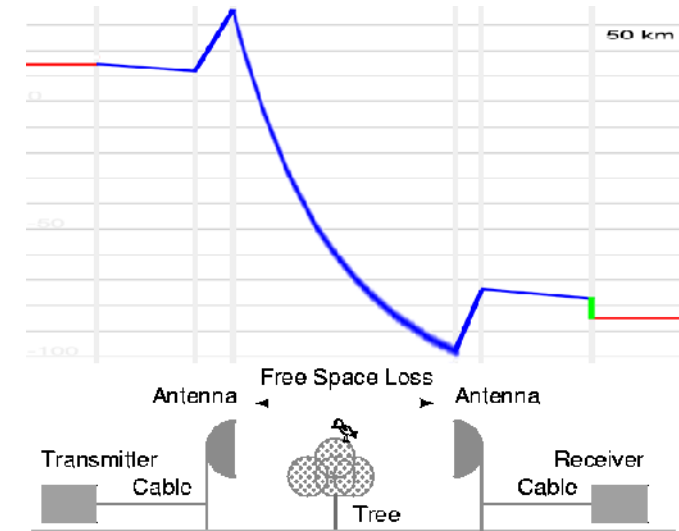
802.11 standards



	Data rates [Mbps]	Freq [GHz]	channel access
b	11	2.4	DSSS
g	54	2.4	DSSS, OFDM
a	54	5 GHz	OFDM
n	300/600*	2.4/5	all the above , MIMO
			*20/40 Mhz/channel
ac	> 1000?	2.4/5	OFDM, MU-MIMO
ad	> 6000 (?)	60 (!)	keep in mind: mm waves!
af	(lower)	0.7 a.o. ex-TV	aka White-Fi

Link Budget

- A link budget is mandatory for all long links – point to point, point to multipoint
- Not relevant for a “hotspot” (access network)
- A link budget is simply **adding up all gains and losses** (in dB) to see if what you have in the end (the margin) is enough for a link
- Read more: <http://wtkit.org/groups/wtkit>



Link Budget - elements

- Radio output TX
- Radio sensitivity RX
- Cables on both sides
- Antennas on both sides
- And **a lot of**

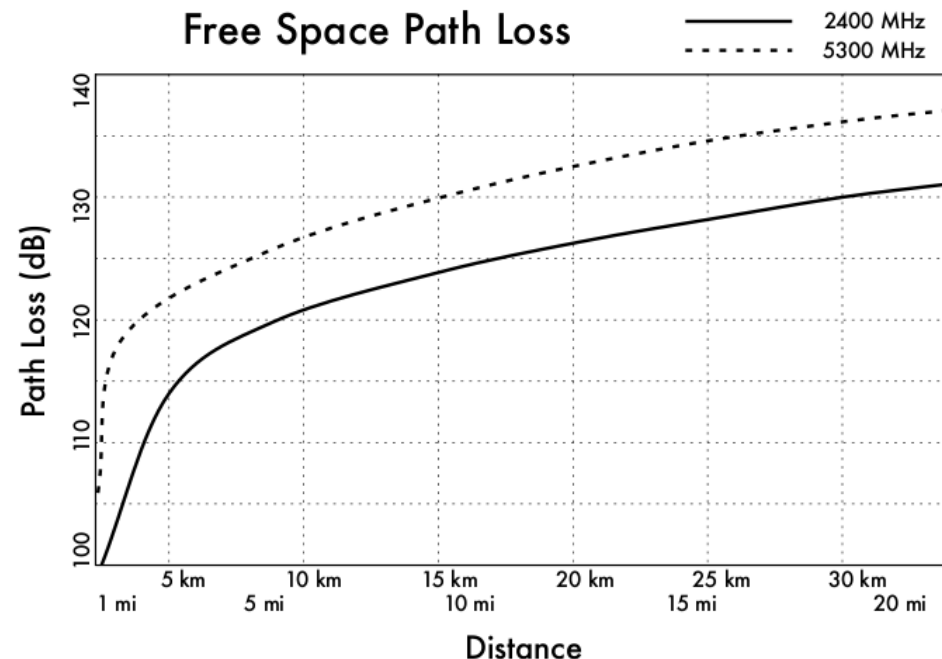
Free space loss

$$\text{FSL [dB]} = C + 20 * \text{Log}(D) + 20 * \text{Log}(F)$$

D distance, and F frequency [MHz].

C = 36.6 if D [miles] / 32.5 if D [kilometers]

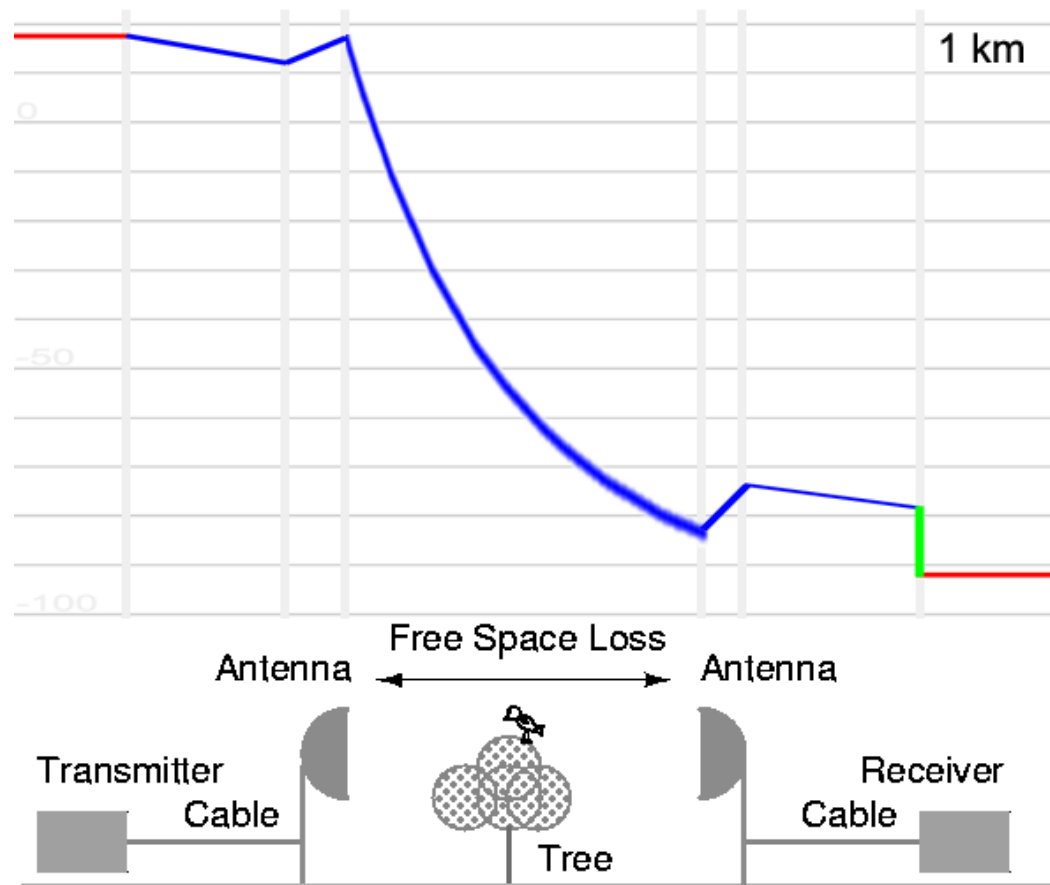
- (Hopefully no) amplifiers



Complete link budget - example

- Transmit output + 018 dBm
 - Cable + Connectors - 005 dB (low quality cabling)
 - Antenna TX + 005 dBi (an omni)
 - FSL (1 km / 0.622 miles at 2.4 Ghz)
- 100 dB
 - Antenna RX + 008 dBi (patch antenna)
 - Cable + Connectors - 005 dB (bad again :)
 - Receive Sensitivity - 092 dBm (subtract!)
-
- **TOTAL + 13 dB margin**

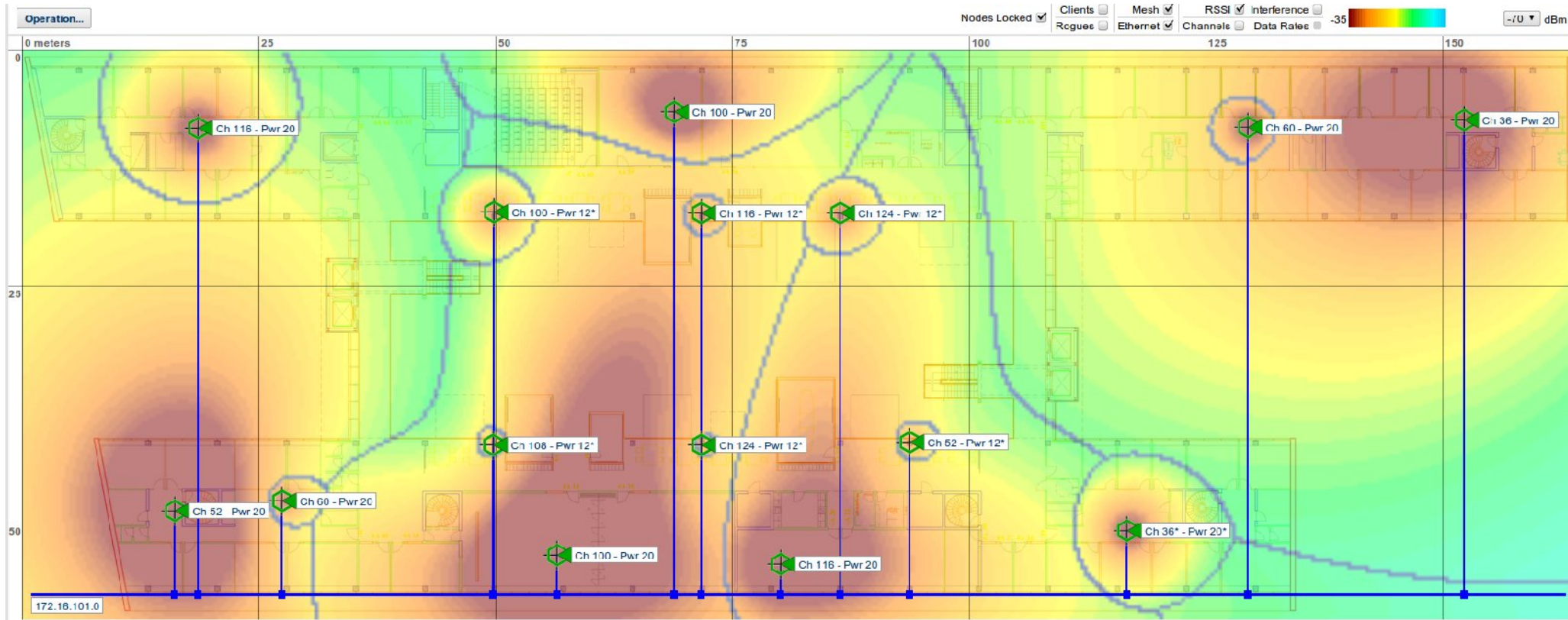
Complete link budget - example



Coverage Maps

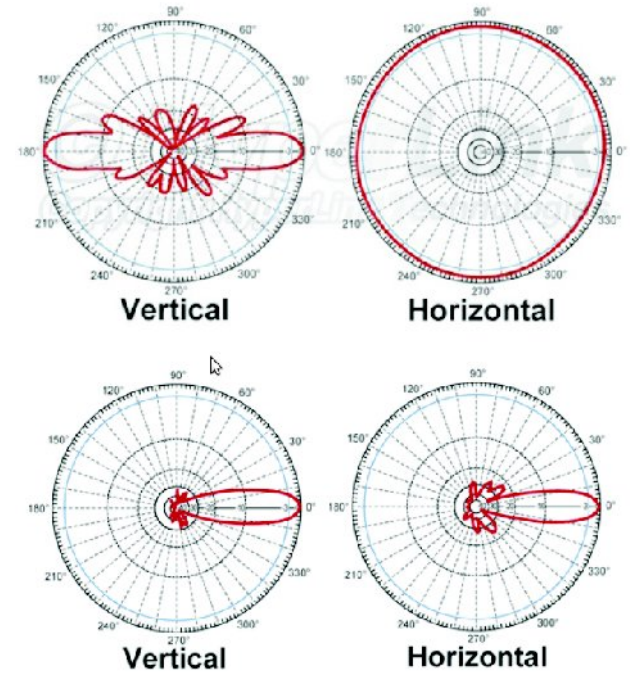
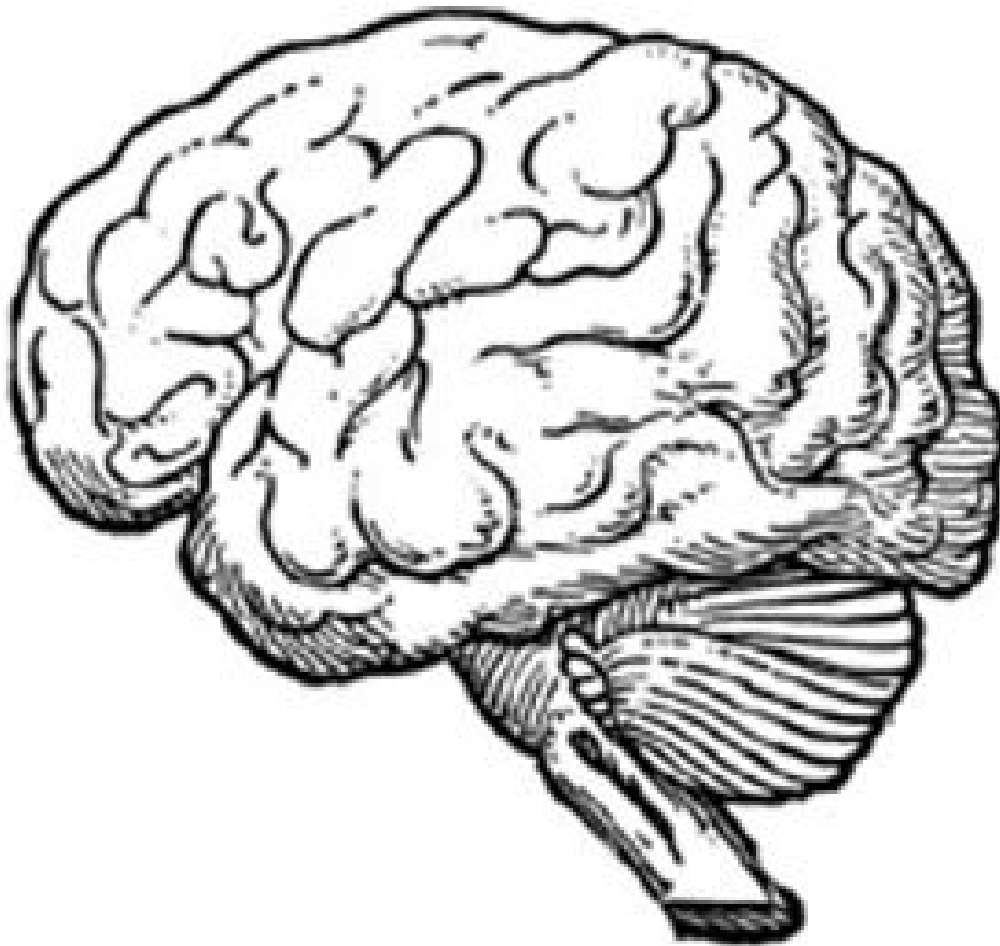
- For point to point links you do Link Budgets, for Access networks (point to many point) you do **Coverage Maps**
- May use vendor specific management tools or free tools like
RadioMobile <http://www.cplus.org/rmw/english1.html>
AirLink <http://www.ubnt.com/airlink/>

Coverage Maps



Example shown: Aerohive HiveManager

Antennas





Antennas



IP design

Same principles as for wired networks

- Route at the core, switch at the edge
- Avoid huge flat networks – subnet!
(but – there is a trade-off – see SSID design)
- Avoid NAT
- I will not even mention IPv6 ... ooops, I did it ...

SSID design at the edge

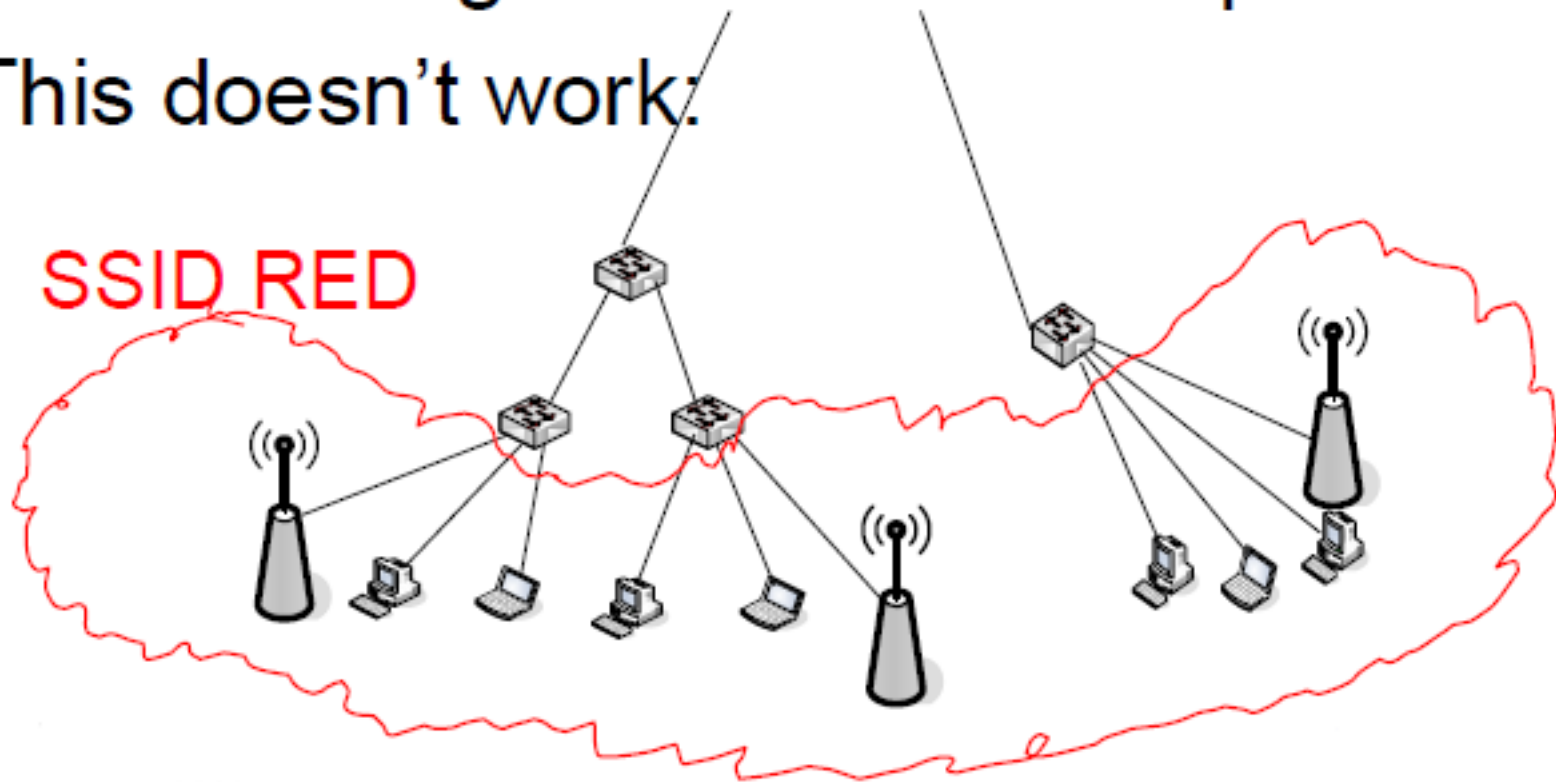
Trade-offs: Structure vs roaming

- If you want seamless roaming, you need to stay in one wireless broadcast domain = one SSID
- SSID design has implications on IP design
- Need to prioritize structure and manageability vs roaming requirements – you cant have all!

SSID design

Roaming with same SSID

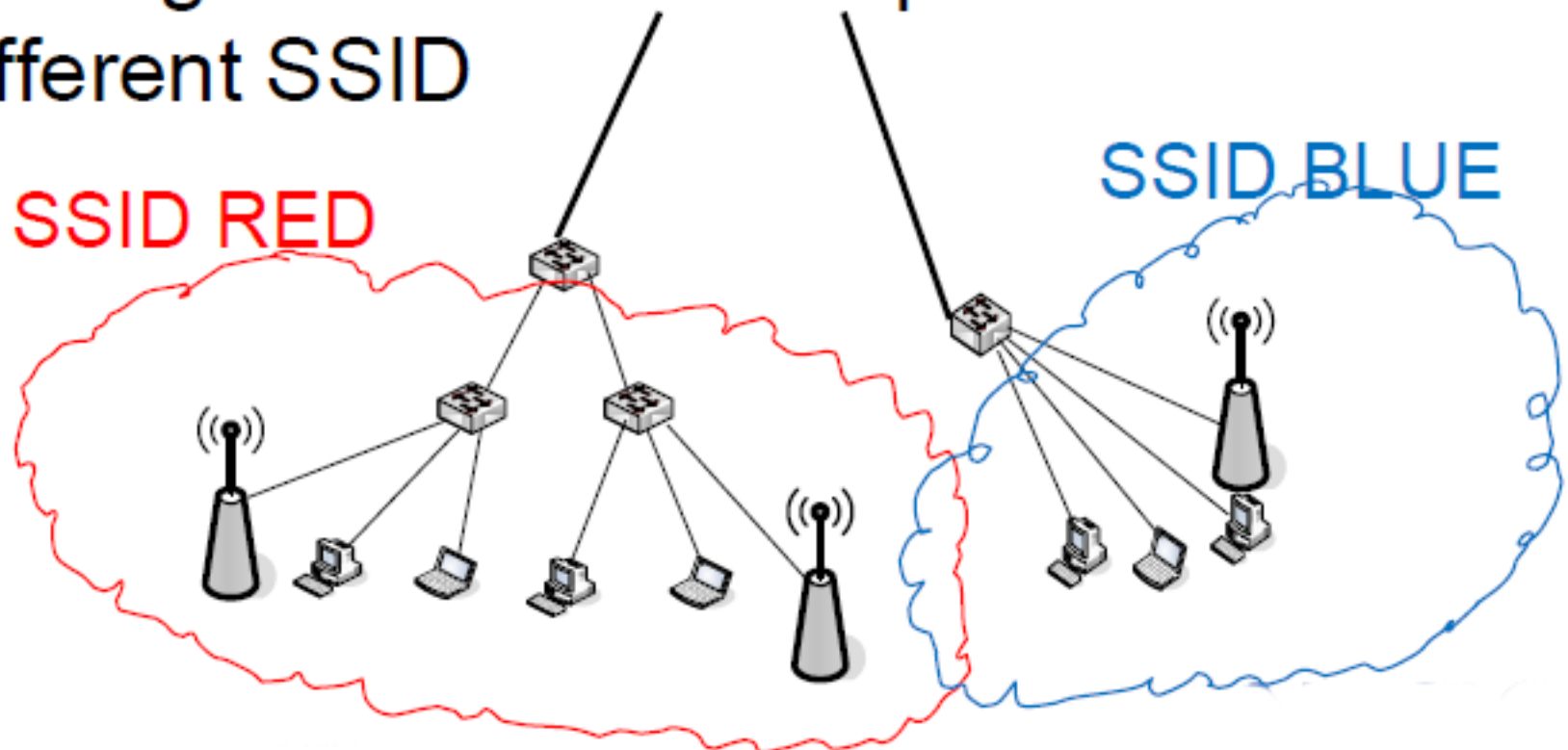
- Same SSID on all access points
- Client will not request new IP address when moving between access points
- This doesn't work:



SSID design

Roaming with Different SSID

- Different SSID on some access points
- Client will request new IP address when moving between access points with different SSID



Access & Authentication

Some comments:

- Keep in mind that **Security is different from Authentication**
- Two relevant methods for authentication:
 - Captive Portals
 - 802.1x / EAPOL
- Both typically draw on RADIUS – AD/LDAP backend
- Sad news: as long as we don't strictly insist on validating SSL certificates, **consider all of this fairly broken ...**
- Keeping people out of your network does not equal security – sometimes it is the opposite - why?

Wireless longshots

What is possible?

- Up to 10 kms: easy with two cans :) and 2 hours of time
- Up to 50 km: better have parabolic dishes, and give it an afternoon
- Up to 100 km: serious dishes and a day or some
- Beyond 100 km: getting serious ...

World record: Ermanno Pietrosemoli and team, 382 km

Wireless longshots

Important aspects:

- Link budget & Link simulation: e.g. with RadioMobile
- Fresnel zones and earth curvature
- Protocol timing issues:
speed of light is not infinite –
1ms for 300 km → ACK timeouts become relevant for
long links → need to hack the WiFi protocols or use
proprietary (TDMA) extensions, e.g. Ubiquiti Airmax,
Mikrotik nv2

Wireless longshots

Important aspects continued:

- Serious antenna optimization
- Alignment techniques:
using spectrum analyzers,
strong RF sources (e.g. Video transmitters)
- Process & Communication

Wireless longshots

Real-world long distance links



Profile of a 382 km test at 2.4 GHz performed in April and August 2007, Venezuela.

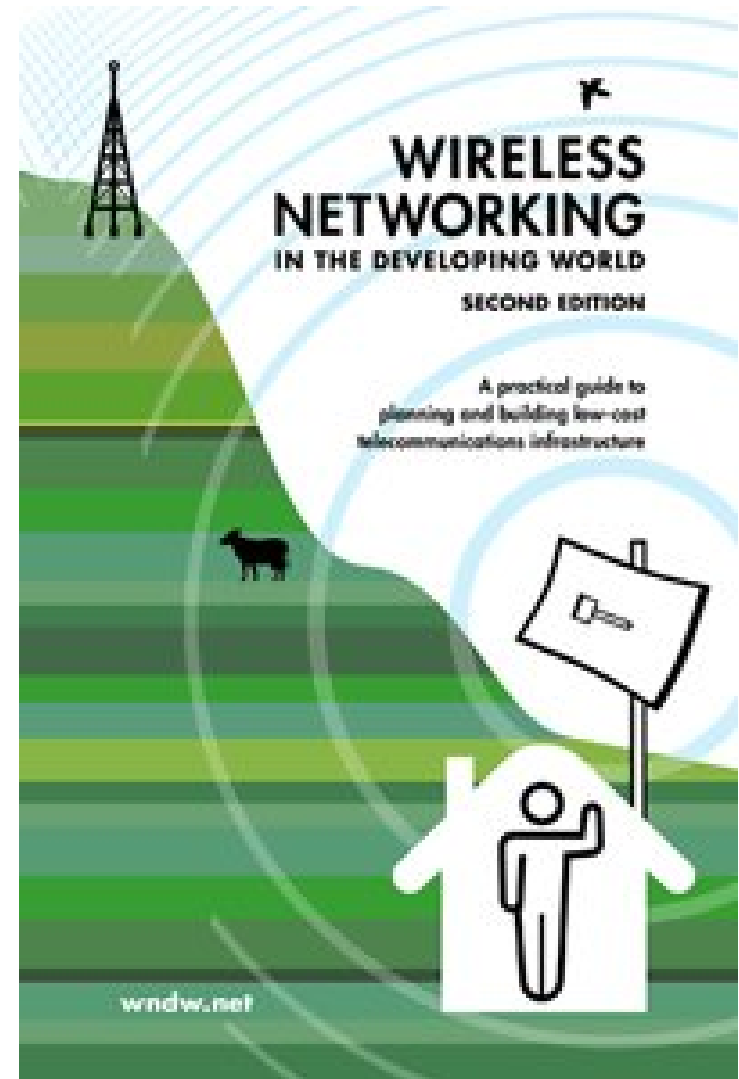
More on all of this ...

**Wireless Networking in the Developing World –
Edition 3 is around the corner (March 2013):**

<http://wndw.net/>

Free

6 languages



More on all of this ...

- NSRC workshop materials <http://nsrc.org>
- ICTP-ITU Kit: <http://wtkit.org/>
- ICTP <http://wireless.ictp.it>

Thanks!

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