

WIRELESS COMMUNICATION. SYSTEM

Modul 12 Capacity Planning



**Faculty of Electrical Engineering
Bandung – 2015**

Tujuan Perencanaan Jaringan

- Tujuan Coverage / Peliputan :
 - Wilayah Peliputan
 - Penetrasi Peliputan
- Tujuan Capacity / Trafik :
 - Jumlah pelanggan
 - Trafik per pelanggan
 - GOS yang diinginkan
- Tujuan Cost / Business dan Logistik :
 - Anggaran Modal
 - Penjadwalan Instalasi dan Penggelaran
 - Laba / Cost pengoperasian Jaringan

Perencanaan Kapasitas & Frekuensi

Perencanaan Kapasitas

- Target perencanaan kapasitas
- Mendefinisikan jumlah carrier atau kanal tiap sel
- Membagi kanal trafik antara GSM/GPRS/EDGE/UMTS/LTE

Input data untuk perencanaan kapasitas

- Besarnya trafik, kerapatan dan distribusinya
- Peramalan trafik untuk 1- 3 tahun kedepan

Perencanaan Frekuensi

- Target perencanaan frekuensi
- Penugasan kanal / carrier tiap BTS
- Mengikuti persyaratan perencanaan kapasitas
- Menjamin kualitas layanan tetap baik

Input data untuk perencanaan frekuensi

- Jumlah TRX tiap BTS
- Persyaratan C/I , probabilitas interferensi
- Fitur yang diminta (frequency hopping, ...) untuk C/I

Perencanaan Parameter & Verifikasi

Perencanaan Parameter

- Target pada perencanaan parameter
- Untuk menjamin kesuksesan permintaan call dan pemutusan call
- Signalling, radio resource management, mobility management, measurements, handovers, power control

Input data untuk perencanaan parameter

- Trafik Signalling , location area, jumlah call
- Coverage area, neighbour base station

Verifikasi

- Target pada proses verifikasi
- Pengujian fungsional jaringan

Input data untuk proses verifikasi jaringan

- Radio network plan (coverage, capacity, frequency)
- Radio network parameter
- Radio network measurement (NMS, test mobile)

Optimasi & Monitoring

Optimisasi

- Target pada proses optimisasi
- "re-plan" jaringan
- Meningkatkan efisiensi, fungsionalitas dan QoS jaringan

Input data for the optimisation process

- Radio network plan
- Radio parameter
- Hasil monitoring (key performance indicator)

Monitoring

- Target proses monitoring
- Analisa kualitas jaringan
- Pengamatan "bottlenecks" jaringan (coverage, capacity, quality)
- Menyelesaikan masalah dan optimisasi

Input data for the monitoring process

- Identitas BTS
- Periode pengukuran

Tujuan dari Perencanaan

Perencanaan jaringan dimulai dari alokasi lebar pita frekuensi yang diberikan pemerintah kepada suatu operator seluler.

Alokasi lebar pita frekuensi inilah yang digunakan oleh operator untuk memberikan layanan komunikasi dengan kualitas komunikasi yang sebaik-baiknya dan untuk sebanyak-banyaknya user.

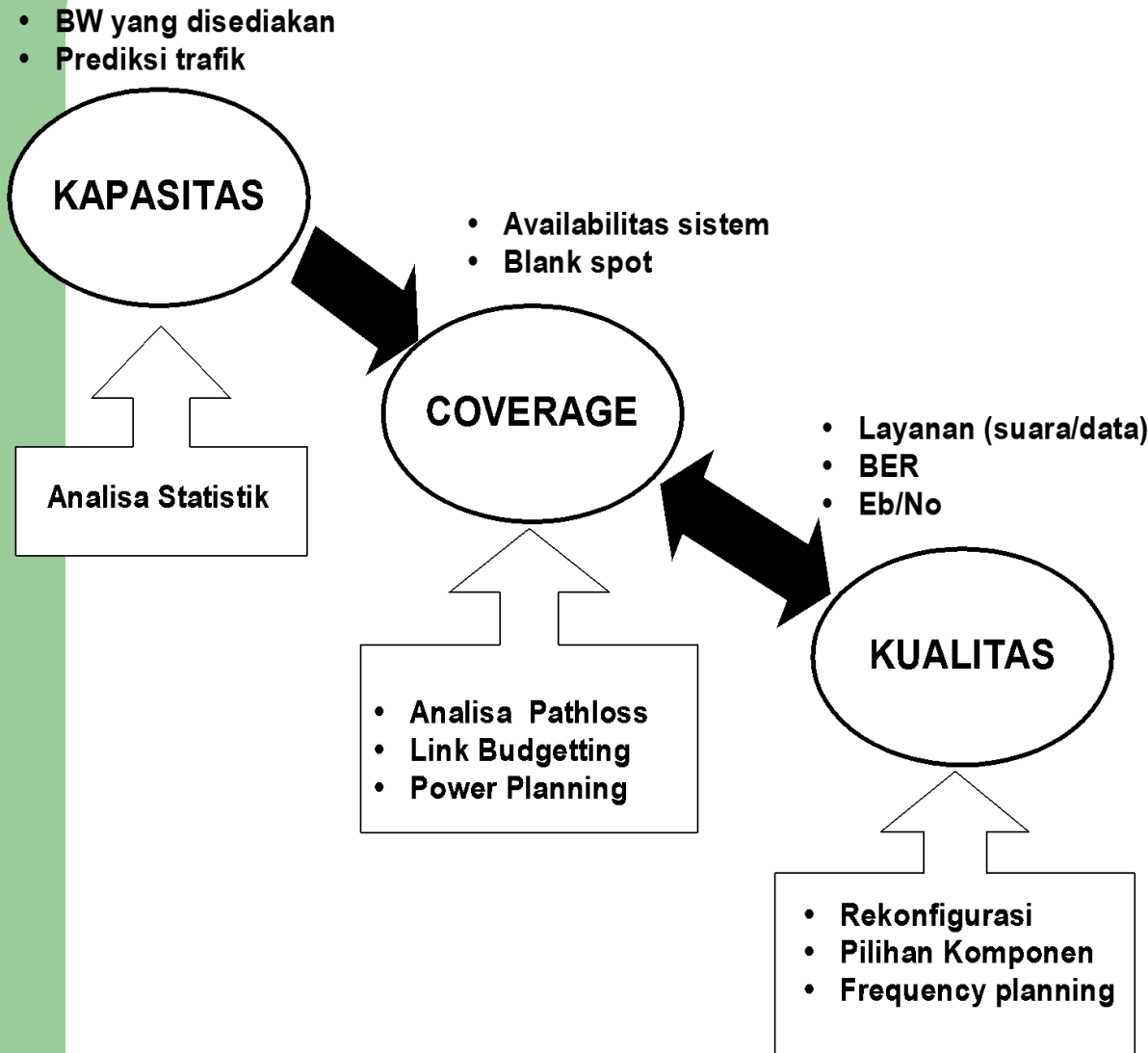
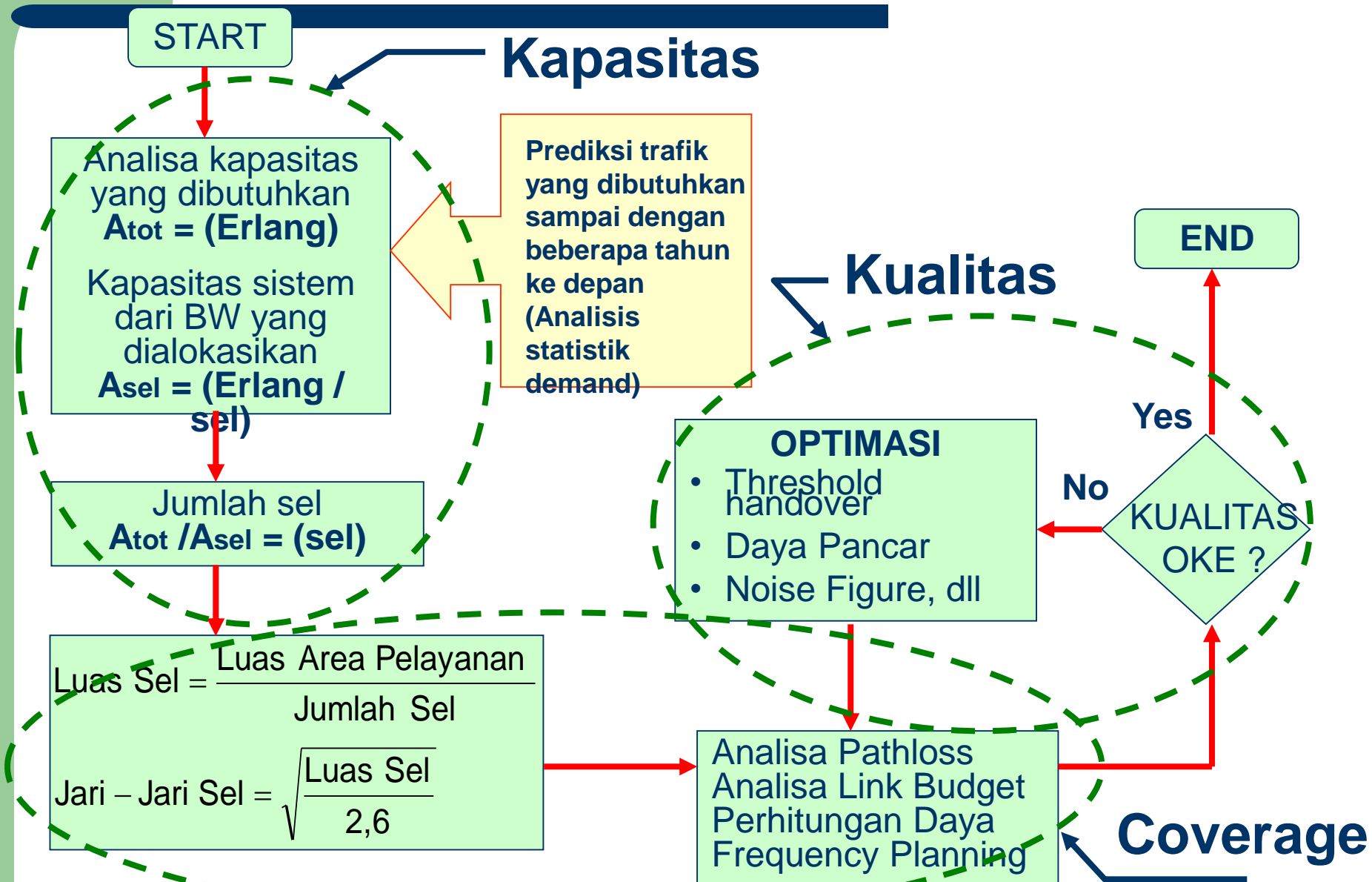
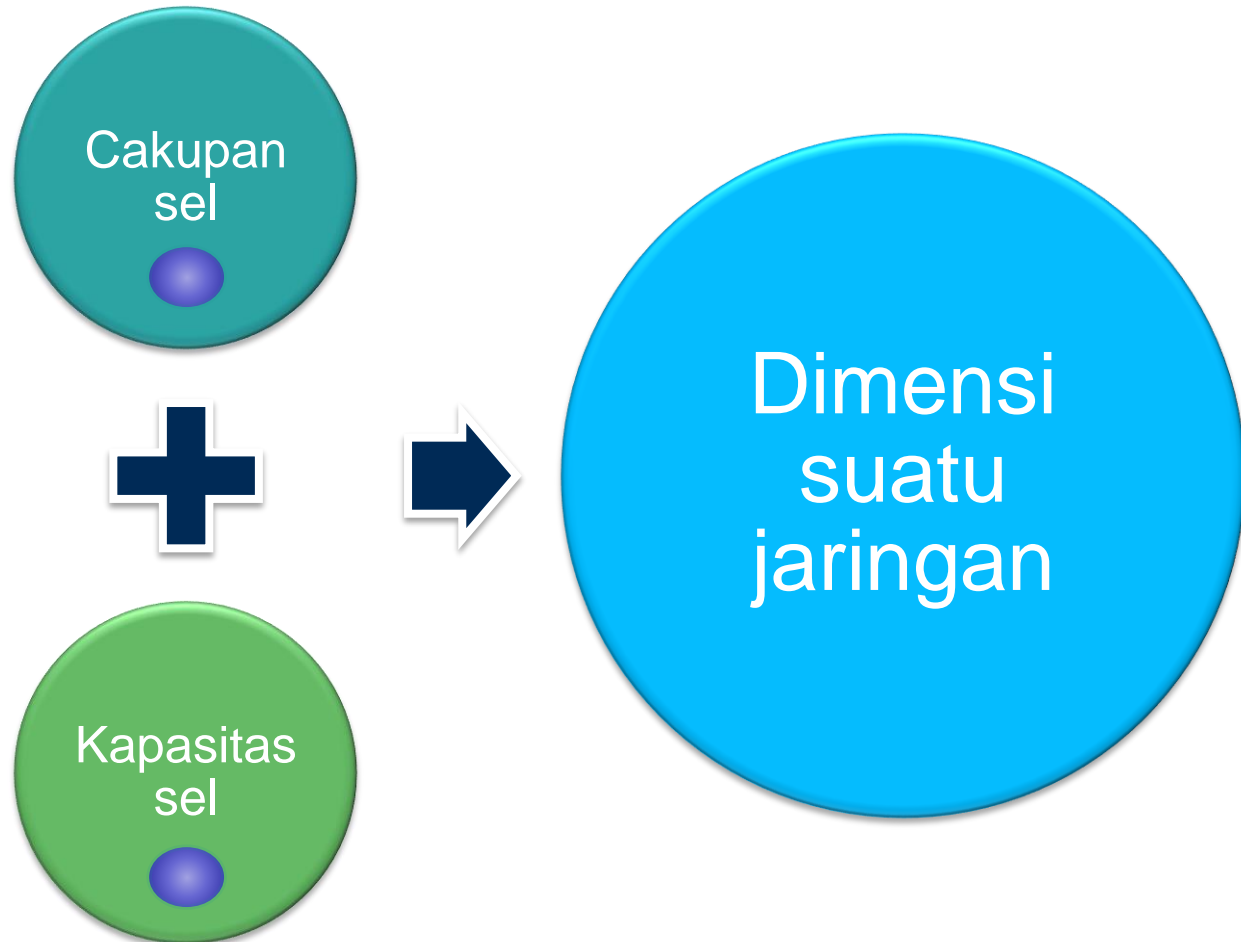


Diagram Alir Perencanaan Sel



Pendimensian Jaringan dalam Analisis Techno-Economics



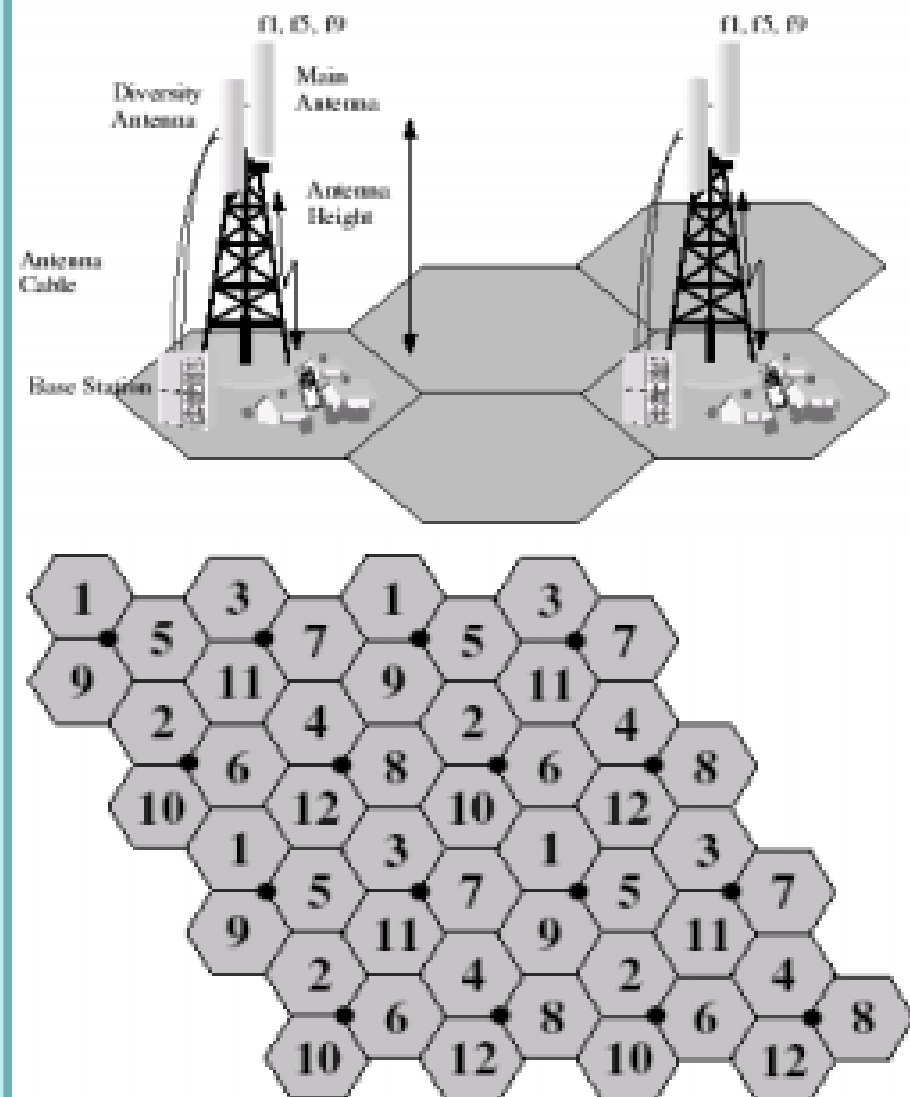
Istilah Coverage dan Capacity

• Coverage

- signal-to-noise ratio (SNR)
- path loss
- radio propagation environment
- radio propagation slope
- location probability
- coverage limited

• Capacity

- Frequency
- Channel
- Frequency reuse factor or number
- Co-channel carrier-to-interference ratio (C/I)
- Time slot
- Traffic and signalling channel
- Blocking
- Capacity limited



Dimensioning

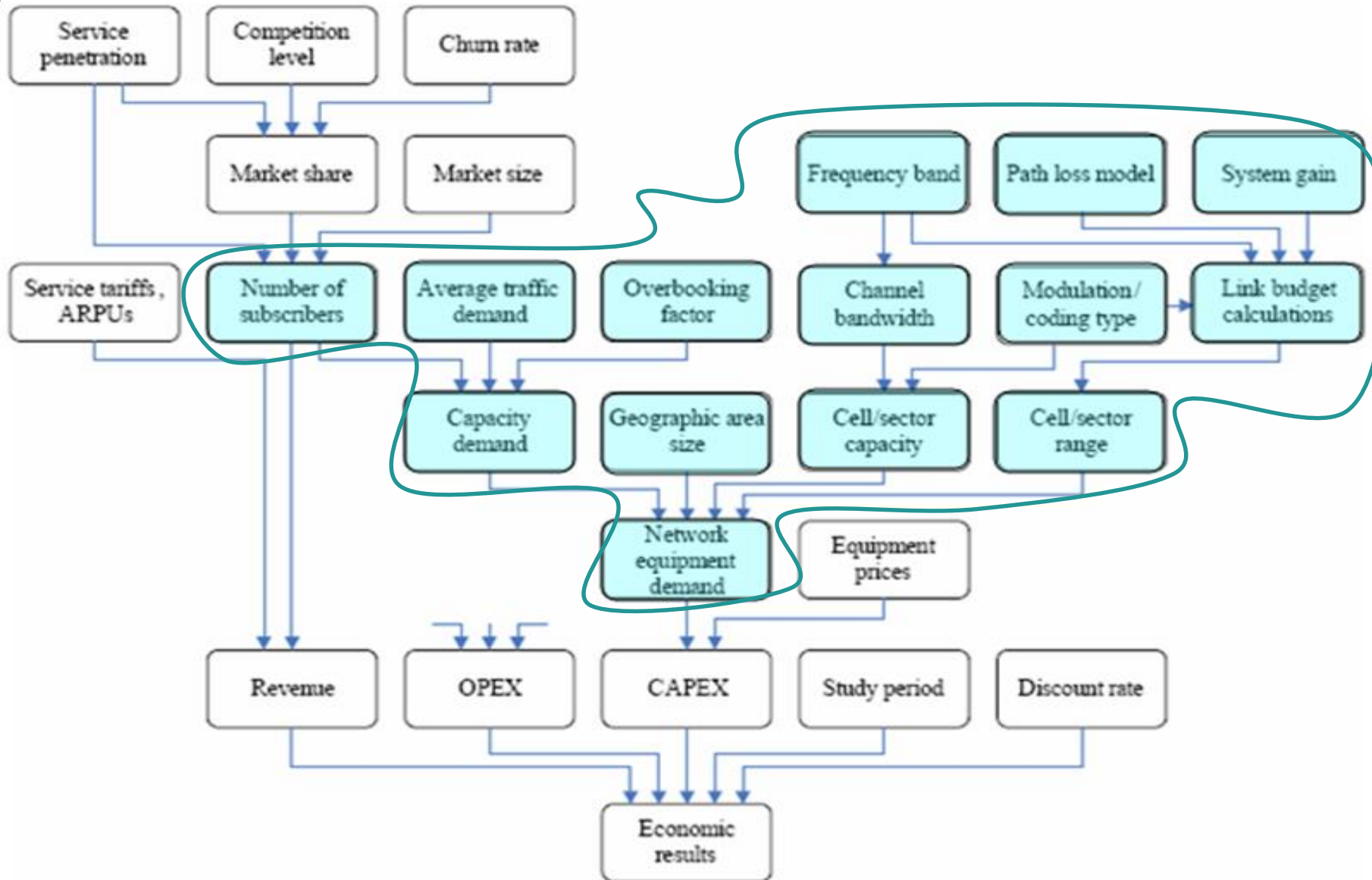
Target-target dimensioning

- Konfigurasi jaringan radio (tinggi antena, jumlah BTS)
- Strategi penggelaran (single/dual band, macro/microcellular)

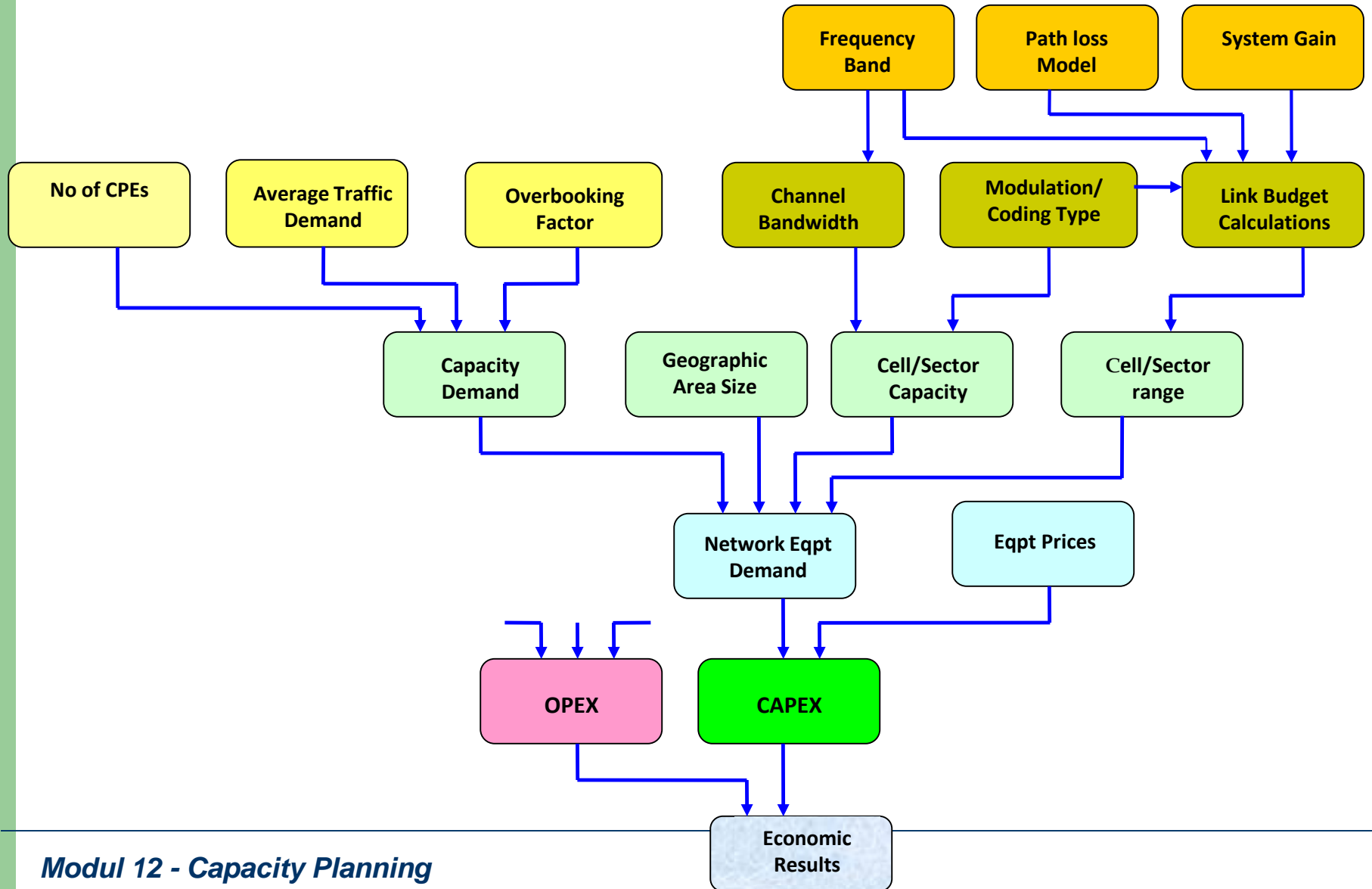
Input data untuk dimensioning

- Ukuran coverage area
- Threshold coverage
- Teknologi radio dan band frekuensi
- Path loss antara BTS dan SS
- Total trafik pada coverage area
- Target blocking maksimum (0.01..0.05)
- Bandwidth yang tersedia
- Frequency reuse

Analysis Techno-Economics



Wireless Cellular Network Design Flow Sequence



Kategori Pelanggan

Untuk perencanaan kapasitas, pelanggan dibagi menjadi 3 kategori

● Professional User:

- Pelanggan yang membutuhkan Mobile Broadband Access untuk tujuan bisnis dan juga personal.
 - E-mail, video conferencing, file downloads, etc.
 - Akses mobile dan nomadic broadband dibutuhkan untuk mempertahankan komunikasi ketika commuting, meeting with clients, inspecting remote job sites, dll.

● High-End Consumer:

- Pelanggan dengan high usage, dengan penggunaan aplikasi untuk keperluan personal lebih tinggi dibanding bisnis.
 - Web browsing, gaming, music downloads, dll.

● Casual User:

- Pelanggan yang menginginkan akses secara periodik, hanya beberapa jam per hari.
 - web browsing

Pengertian Kapasitas

- Kapasitas suatu jaringan wireless (fixed/mobile) didefinisikan sebagai jumlah dari user-user yang dapat disuport oleh suatu cell site dengan mempertahankan kriteria QoS/GOS tertentu.
- Dapat juga direpresentasikan oleh jumlah user yang diasosiasikan dengan **throughput data** dan kriteria QoS tertentu.
- Spektrum RF yang tersedia, mempunyai kaitan langsung dengan kapasitas yang bisa diberikan.
- Air Interface yang mampu menggunakan alokasi spektrum secara efisien, akan menawarkan kapasitas yang lebih besar.

Pengertian Kapasitas

- Selama fase perencanaan penggelaran, setelah operator menetapkan ukuran kanal spektrum radio, pertanyaan berikutnya adalah :

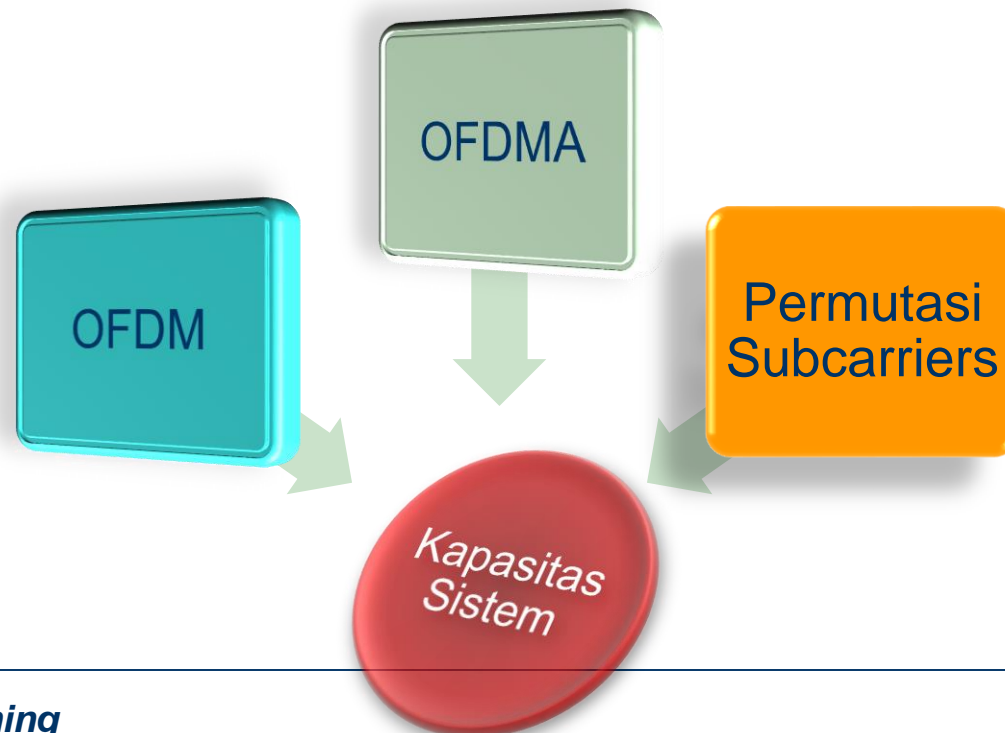
Berapa banyak koneksi data yang dapat disuport oleh kanal tersebut ?

Berapa banyak Base Station yang diperlukan untuk suatu area layanan ?

- Pemahaman terhadap kapasitas sistem adalah kunci untuk menggelar Access Network yang sukses.

Kapasitas Sel (System Capacity)

- Kapasitas sistem adalah kemampuan sistem dalam menyampaikan banyaknya informasi per satuan waktu (bit per detik).
- Menghitung kapasitas sistem Fixed WiMAX
- Menghitung kapasitas sistem Mobile WiMAX:



Perhitungan Throughput

- Faktor yang menentukan throughput yang tersedia pada suatu sektor :
 1. Jumlah data subcarrier yang digunakan per frame OFDM/OFDMA
 2. Tipe Modulasi
 - Terdapat 2 coding rate per modulation rate yang menghasilkan 8 level modulasi yang berbeda :
 - (1) BPSK $\frac{1}{2}$ (2) BPSK $\frac{3}{4}$ (3) QPSK $\frac{1}{2}$ (4) QPSK $\frac{3}{4}$
(5) 16QAM $\frac{1}{2}$ (6) 16QAM $\frac{3}{4}$ (7) 64QAM $\frac{2}{3}$ (8) 64QAM $\frac{3}{4}$
 3. DL/UL duration ratio

Estimasi Jumlah Pelanggan

- Pada implementasi real, jumlah pelanggan harus berdasarkan survey **demand baik mikro** (lingkup kota, data primer, survey demand) maupun makro (national, data sekunder mis. Dari BPS)
- Jumlah pelanggan ditentukan oleh ukuran pasar (market size), target market share dan penetrasi service yang diinginkan,
- **Market Size** menunjukkan seberapa besar pasar broadband yang ada di kota tersebut :
 - Jumlah dan trend pengguna komputer
 - Jumlah dan trend pengguna broadband wireline maupun broadband wireless existing
- **Penetrasi layanan yang diinginkan**
 - Jenis layanannya (product)
 - Segmentasi pelanggan yang disasar (umur, belanja telekomunikasi, dlsb)
- **Target market share ditentukan oleh**
 - Kompetitor dan level kompetisi
 - Rata-rata pelanggan yang pindah (churn rate)
 - Operator lama atau operator baru

Kebutuhan Jumlah Base Station

Kebutuhan jumlah BS untuk suatu area tertentu ditentukan oleh

- **Capacity Demand, berapa total “bps” yang dibutuhkan oleh area tersebut yang dihitung mencakup kebutuhan 3 – 5 tahun ke depan.** Kebutuhan kapasitas ditentukan oleh
 - Jumlah pelanggan mencakup pertumbuhannya 3-5 thn ke depan
 - Rata-rata trafik per pelanggan (desain layanan)
 - Over booking yang menyatakan resource tersebut disediakan secara sharing (untuk berapa pelanggan ?) atau eksklusif (tanpa sharing)
- **Luas wilayah, luas kota dimana BS akan dipasang dan kategorinya apakah urban, sub-urban atau rural**
- **Radius per sector BS**
- **Kapasitas per sector BS**

Estimasi Jumlah Pelanggan

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Market Size menunjukkan seberapa besar pasar broadband yang ada di kota tersebut :

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Target market share ditentukan oleh

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- Operator lama atau operator baru

Traffic Forecasting

Traffic Forecasting

- Penetration & total subscribers
- Customers, gross adds, churn
- Voice, data and other source of revenues
- User growth up to maturity of the network.
- As initial works to measure the required capacity

Demographic Anatomy of Targeted Market (i-th year!)

Total Population

100%

60% With Sufficient Income

70% Old Enough

to Own

Mobile Phone

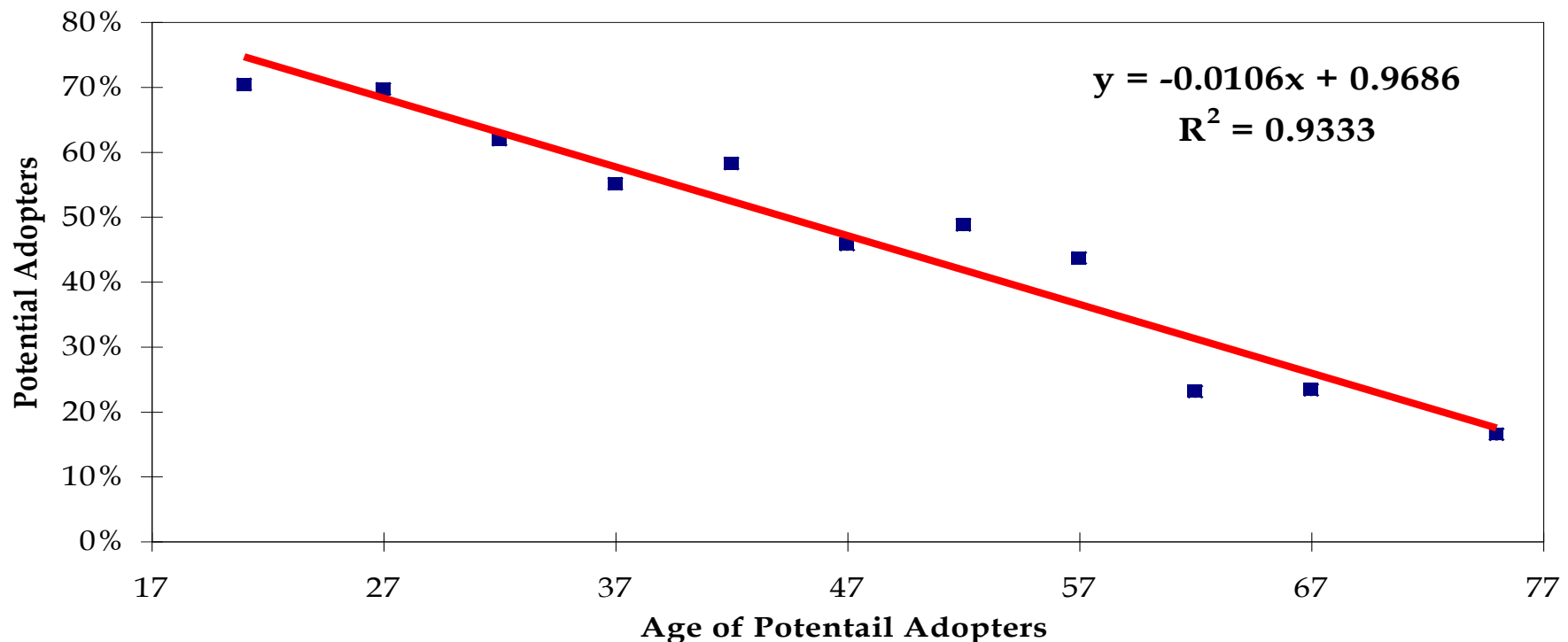
Addressable Market 42%

80% Expresses Interest:
Potential Demand 33.6%
of Population

Propensity to Adopt Mobile Comm. by Age example from Western European country: Age is an important discriminator.

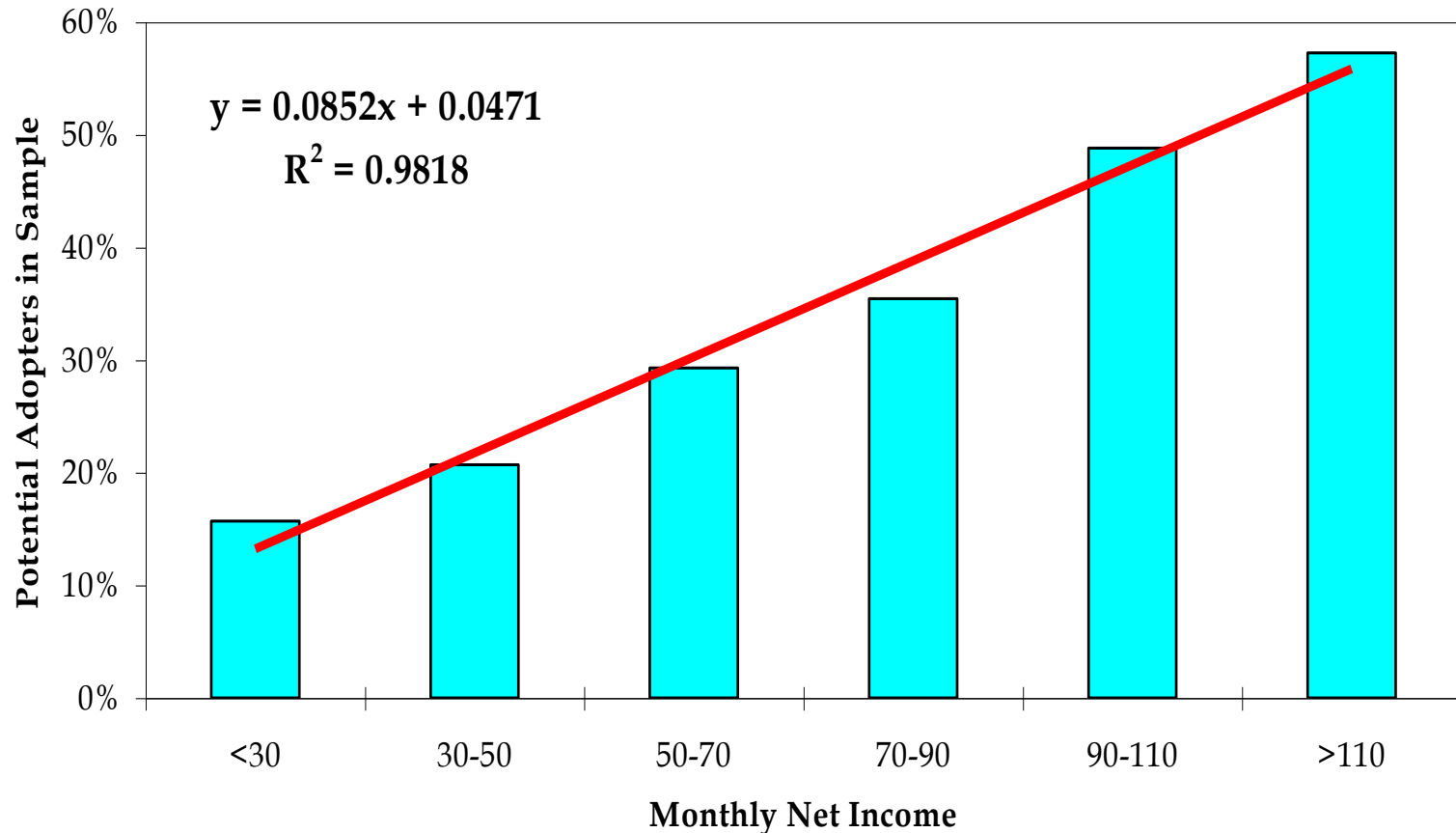
A Western European country, sample 1,000 interviews 1997

Propensity to Adopt by Age



Correlation between propensity to adopt mobile & income example lower income country: Income matters.

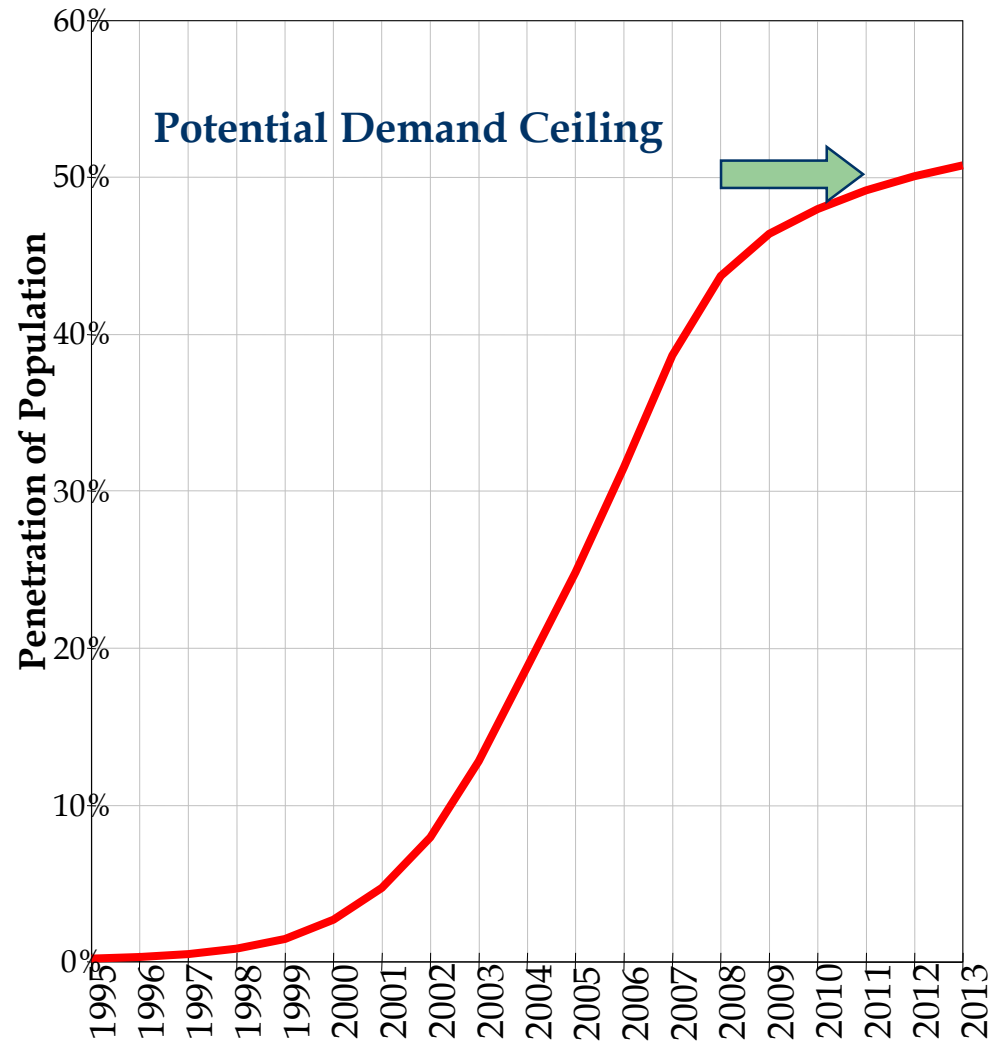
Propensity to Adopt Cellular by Income



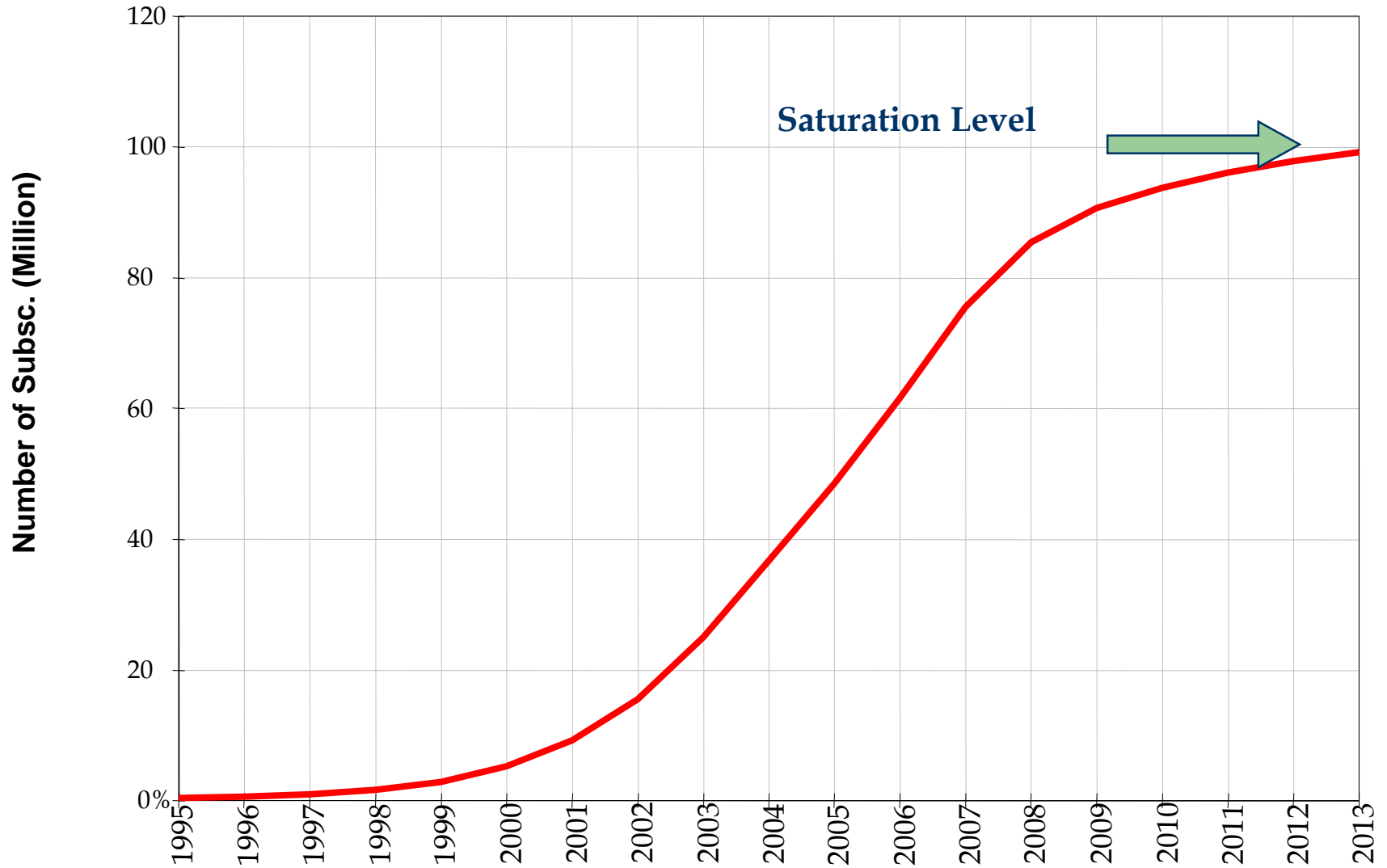
A Far Eastern country, sample 1,500 interviews 1996

Penetration Growth

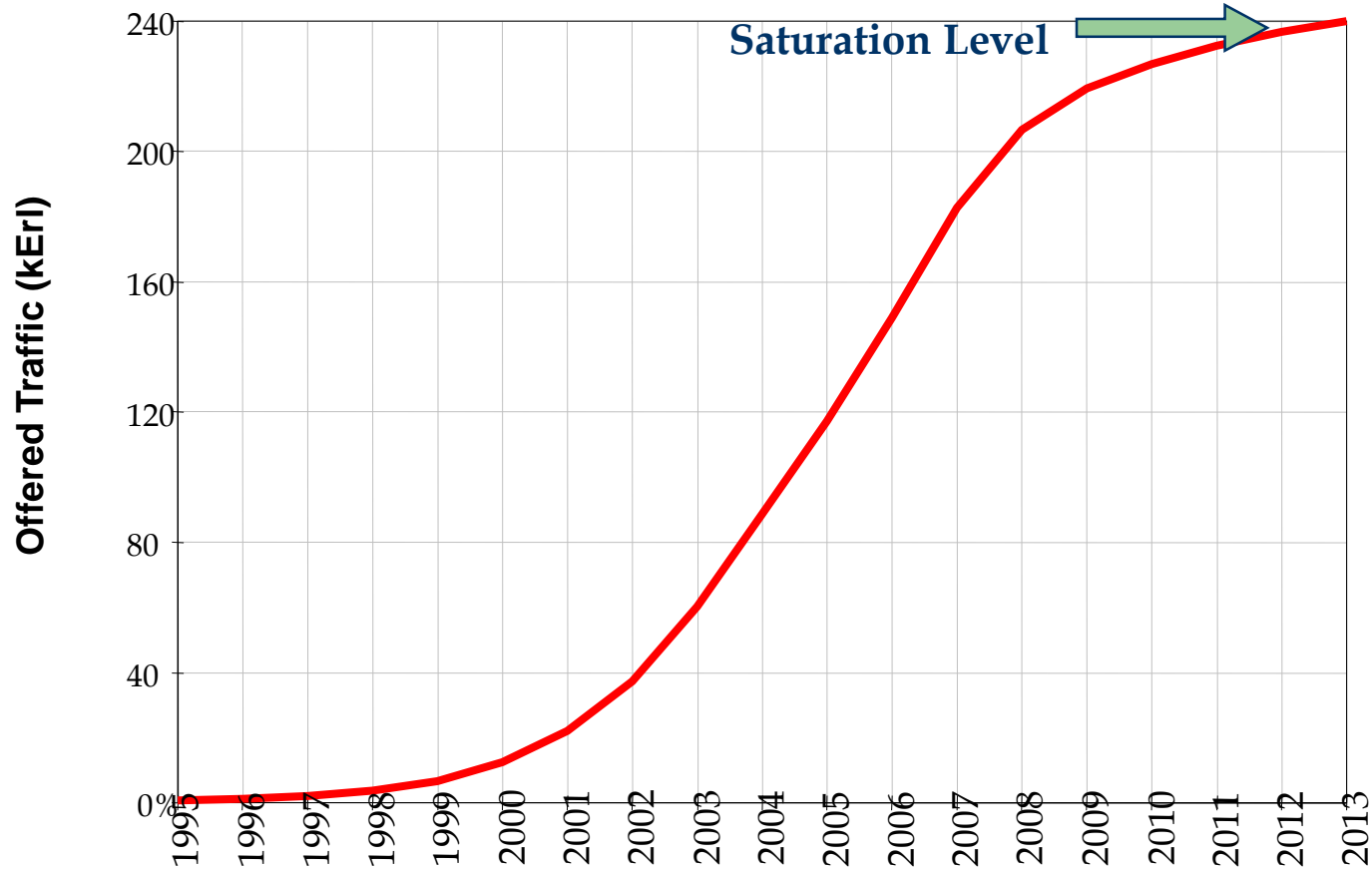
- ❑ The potential demand assumptions should be linked to changing demographic patterns and changes in income.
- ❑ The potential demand sets a penetration ceiling, conceptually the maximum potential penetration is the level at which the service life cycle curve reaches its upper limit.



Growth of Subscribers



Traffic Growth



- e.g voice traffic/user = 27 mErl which comprises 80% of total traffic, Data traffic/user = 10 mErl which is the rest of total traffic. Combined average generated traffic per user is 23.1 mErl.

The Traffic Data from the Marketing Model Drives Network Dimensioning.

- Because the model is intended to be used in the business-planning phase, it is essential that a range of scenarios can be evaluated rapidly.
- The impact of varying, for example, different tariffs can be calculated instantly.
- The engineering model can run completely in the background so that business planners can run scenarios without recourse to engineering.

The Engineering Model covers Capex and Opex for 2G and 3G Networks.

- The capex and opex part of the 3G Mobile Toolkit covers the technical aspects, including capital and operational expenditures.
- The scope of the 3G engineering model includes dimensioning and costing for the following elements:
 - Radio network
 - Core network & interconnect
 - Server network



PLANNING CAPACITY

Calculation steps:

1. Number of user
2. User density
3. Services and Type
4. Penetration : building, vehicular, pedestrian
5. BHCA and call duration
6. OBQ
7. Site calculation

Nominal Planning By Capacity

1. Number of User

$$U_n = U_o (1 + gf)^n$$

U_o is U_{o_u} or $U_{o_{sub}}$

$$U_{o_u} = u \times U_{oN}$$

$$U_{o_{sub}} = sub \times U_{oN}$$

Where:

$$U_{oN} = a \times b \times d \times N$$

- U_n : num of user on year 'n'
- U_o : initial num of user (based on urban/sub-urban)
- a : percent of cellular user (%)
- b : penetration of operator A (%)
- d : Percent of LTE user
- N : num of civilian in the object area
- gf : num of user growth factor
- n : planned year
- u/sub : urban or sub-urban penetration (%)

Customer Prediction Parameter

Nominal Planning By Capacity

Ex :

- Population = 1445892 people
- Cellular penetration = assumption 80%
- LTE penetration = assumption 10 %
- LTE provider A penetration = assumption 50 %

Population	1445892	people
Customer cellular (80%)	1156713	user
Customer LTE (10%)	115671	user
Customer LTE provider A (50%)	57835	user

User prediction in 5th years

- $U_5 = 57835 (1 + 0.05)^5 \rightarrow$ assumption fp=5%
= **73814** user

Example User Calculation

Ex :

- urban penetration = assumption 60 %
- suburban penetration = assumption 40 %
- Urban user = $73814 \times 60 \%$ = **44288** user
- Suburban user = $73814 \times 40 \%$ = **29525** user

2. User Density

$$L_u = L \times u$$

$$L_{sub} = L \times sub$$

- L_u : urban area wide
- L_{sub} : sub-urban area wide
- L : object area wide

$$C_u = Un / L_u$$

$$C_{sub} = Un / L_{sub}$$

- C_u : Urban area density
- C_{sub} : sub-urban area density

Example User Density Calculation

Ex :

- urban area penetration = assumption 40 %
- suburban area penetration = assumption 40 %
- Openarea = assumption 20 %

=>

Urban area wide (Lu) : 242,928 km²

Sub-urban area wide (Lsub) : 242,928 km²

=>

$$C_u = 44288 / 242,928 = 182,31232 \text{ user/km}^2$$

$$C_{\text{sub}} = 29525 / 242,928 = 121,54155 \text{ user/km}^2$$

3. Services and Type

- Services (Rb)
 - VoIP : 64 kbps
 - FTP : 1000 kbps
 - Video : 384 kbps

- Type (c)
 - Building : 50 %
 - Vehicular : 30 %
 - Pedestrian : 20 %

4. Penetration

- **Penetration (p) per type per service**

e.g: BUILDING VoIP usage penetration = 0.5
BUILDING FTP usage penetration = 0.4
PEDESTRIAN Video usage penetration = 0.3

- **BHCA (B) per type per service**

e.g: BUILDING VoIP usage penetration = 0.008
BUILDING FTP usage penetration = 0.009
PEDESTRIAN Video usage penetration = 0.008

- **Call duration (h) per type per service (ms)**

e.g: BUILDING VoIP usage penetration = 60
BUILDING FTP usage penetration = 50
PEDESTRIAN Video usage penetration = 50

Penetrasi User (p)			
	Building	Pedestrian	Vehicular
Voip	0,5	0,5	0,2
Video	0,3	0,3	0,2
FTP	0,4	0,4	0,3

type	call duration (h)		
	voip	video	ftp
building	60	40	50
pedestrian	60	50	70
vehicular	60	40	80

service	net user bit rate (Rb)
VoIP	64000
FTP	1000000
Video	384000

BHCA (B)			
Service	Building	Pedestrian	Vehicular
Voip	0,008	0,008	0,009
Video	0,007	0,008	0,009
FTP	0,009	0,008	0,008

6.OBQ (Offered Bit Quantity)

- VoIP

$$OBQ_T = c_T \times C_{u;T} \times p_T \times Rb_{VoIP} \times B_T \times h_T$$

- FTP

$$OBQ_T = c_T \times C_{u;T} \times p_T \times Rb_{FTP} \times B_T \times h_T$$

- Video

$$OBQ_T = c_T \times C_{u;T} \times p_T \times Rb_{Vid} \times B_T \times h_T$$

T : Type (Building; Vehicular; Pedestrian)

Note: if T= pedestrian, then “OBQ_T” is pedestrian OBQ, “B_T” is pedestrian BHCA, etc.

OBQ cont'd

$$\text{OBQ}_{\text{total}} = \text{OBQ}_{\text{VoIP}} + \text{OBQ}_{\text{FTP}} + \text{OBQ}_{\text{Video}}$$

Where:

$$\text{OBQ}_{\text{VoIP}} = \text{OBQ}_{\text{vehicular}} + \text{OBQ}_{\text{building}} + \text{OBQ}_{\text{pedestrian}}$$

$$\text{OBQ}_{\text{FTP}} = \text{OBQ}_{\text{vehicular}} + \text{OBQ}_{\text{building}} + \text{OBQ}_{\text{pedestrian}}$$

$$\text{OBQ}_{\text{Video}} = \text{OBQ}_{\text{vehicular}} + \text{OBQ}_{\text{building}} + \text{OBQ}_{\text{pedestrian}}$$

OBQ cont'd

OBQ			
Service	Building	Pedestrian	Vehicular
Voip	1,400158616	0,5600634	0,252029
Video	2,940333094	5,2505948	1,008114
FTP	16,40810878	8,1675919	7,000793
Σ	20,74860049	13,97825	8,260936

$$\text{OBQ}_{\text{total}} = 20,74860049 + 13,97825 + 8,260936 = 42,98779$$

eNodeB Capacity

$$PeakBitRate [Mbps] = \frac{bit}{Hz} \times N_{subcarriers} \times \frac{N_{symbol-per-subframe}}{1ms}$$

Bandwidth (MHz)	Modulation		
	QPSK	16 QAM	64 QAM
1.4	2.016 Mbps	4.032 Mbps	6.048 Mbps
3	5.04 Mbps	10.08 Mbps	15.12 Mbps
5	8.4 Mbps	16.8 Mbps	25.2 Mbps
10	16.8 Mbps	33.6 Mbps	50.4 Mbps
15	25.2 Mbps	50.4 Mbps	75.6 Mbps
20	33.6 Mbps	67.2 Mbps	100.8 Mbps

7.Site Calculation

- Site (L)

$$\begin{aligned} L &= (50.4 \times 3) / \text{OBQtotal} \\ &= (50.4 \times 3) / 42,98779 = \mathbf{3,5172778} \quad \text{km}^2 \end{aligned}$$

50.4 Mbps ---> (asumption: using 64 QAM 1/1, BW = 10 MHz)

- Radius (d)

$$\begin{aligned} d &= (L / 2.6 / 1.95) ^ 0.5 \\ &= (3,5172778 / 2.6 / 1.95) ^ 0.5 = 0,832912489 \text{ km} \end{aligned}$$

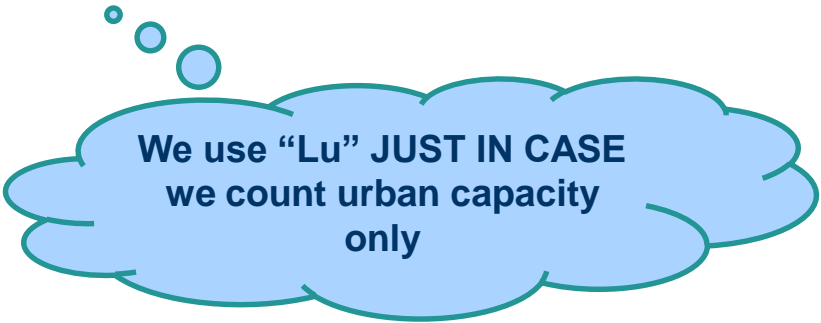
Site Calculation Con't

- Number of eNodeB (M)

$$M = \underline{Lu} / L$$

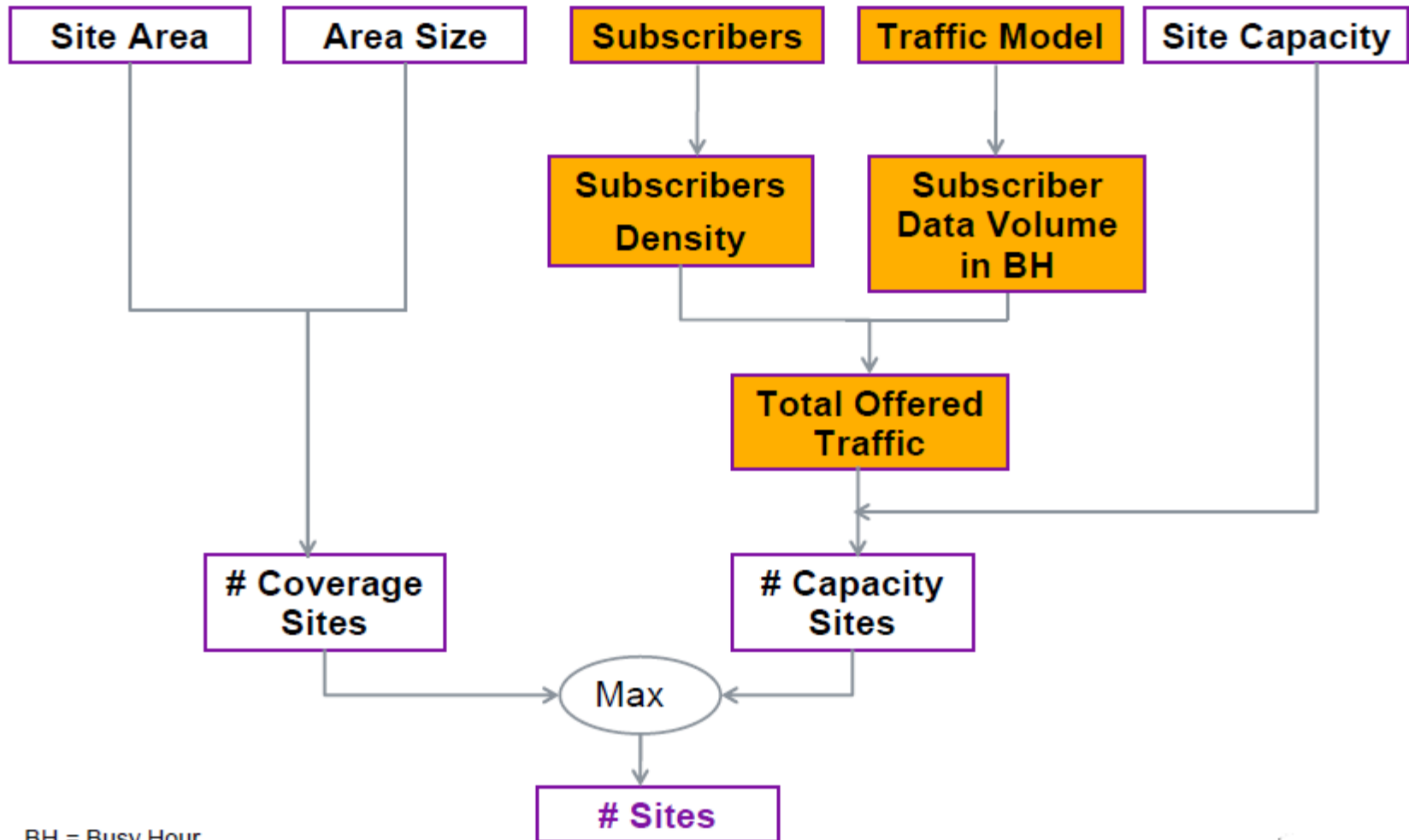
$$= 242,928 \text{ km}^2 / \mathbf{3,5172778} \text{ km}^2$$

$$= 69,06704366$$



We use "Lu" JUST IN CASE
we count urban capacity
only

Nominal Planning By Capacity



Nominal Planning By Capacity

● Number Of User

$$U_n = U_o (1 + gf)^n$$

U_o is U_{o_u} or $U_{o_{sub}}$

$$U_{o_u} = u \times U_{oN}$$

$$U_{o_{sub}} = sub \times U_{oN}$$

Where:

$$U_{oN} = a \times b \times d \times N$$

- U_n : num of user on year 'n'
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Nominal Planning By Capacity

● Traffic User Prediction

Typical Subscriber's Profile:

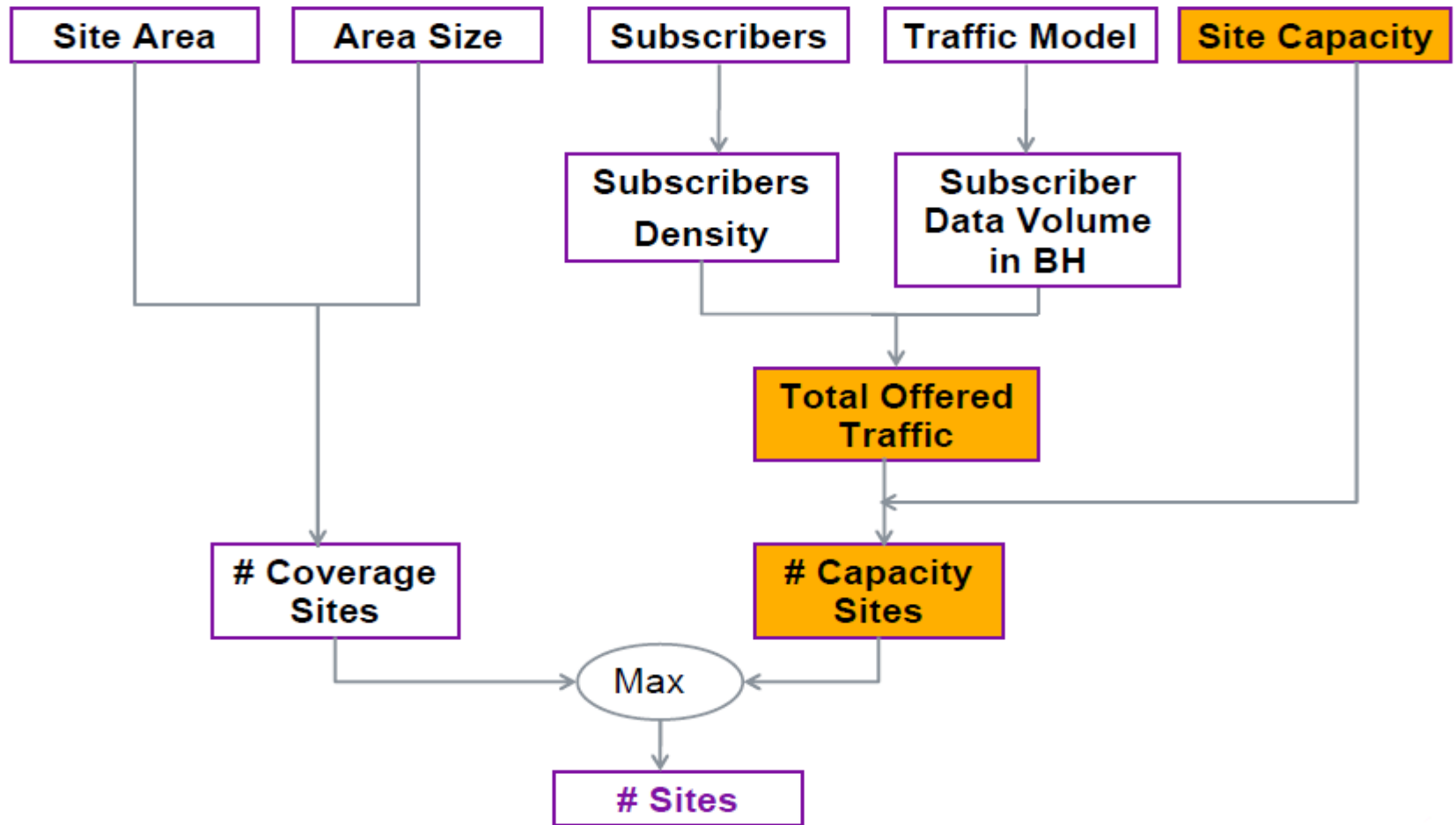
session length/size

	Unit	Value	BHCA
1) Voice dominant subscriber profile			
Voice Usage per Subscriber	min	5	3,3
Video Usage per Subscriber	min	0	0,0
Streaming Usage per Subscriber	min	0	0,0
Web Usage per Subscriber	pages	0,333	0,1
FTP	kB	390,70	0,1
Data Usage per Subscriber	MB	1	
2) Data dominant subscriber profile			
Voice Usage per Subscriber	min	0,1	0,1
Video Usage per Subscriber	min	0,1	0,1
Streaming Usage per Subscriber	min	2	0,2
Web Usage per Subscriber	pages	3,33	0,7
FTP	kB	7747	1,5
Data Usage per Subscriber	MB	10	
3) Voice and data mixed profile			
Voice Usage per Subscriber	min	2,5	1,7
Video Usage per Subscriber	min	0,05	0,0
Streaming Usage per Subscriber	min	1	0,1
Web Usage per Subscriber	pages	2	0,3
FTP	kB	2 914	0,6
Data Usage per Subscriber	MB	5	

NSN Traffic Model (TM)

- Avg. Traffic user / BH
= 10 MB
- Avg. Traffic user / Sub
= 10 MB / 3600 s * 8 bit
= **22.75 Kbps**
- Total Offered Traffic
= 73814 * 22.75
= 1679268.5 Kbps
= **(1680 Mbps)**

Nominal Planning By Capacity



Nominal Planning By Capacity

- Calculate Cell by Capacity

Element	Value	Unit
Cell Capacity	18	Mbps
Sector	3	sector
EnodeB Capacity	54	Mbps
Congestion Control	80	%
Total Offered Traffic	1680	Mbps
No. Of Site	24.88889	Site

- No. Of Site = 25 Site