TTI4A3
Komunikasi Akses Nirkabel

CLO 3 Radio Access Network Dimensioning

Minggu 13:
CAPACITY PLANNING

Outline

CLO 3

Radio Access Network Dimensioning

Minggu 13 Capacity Planning

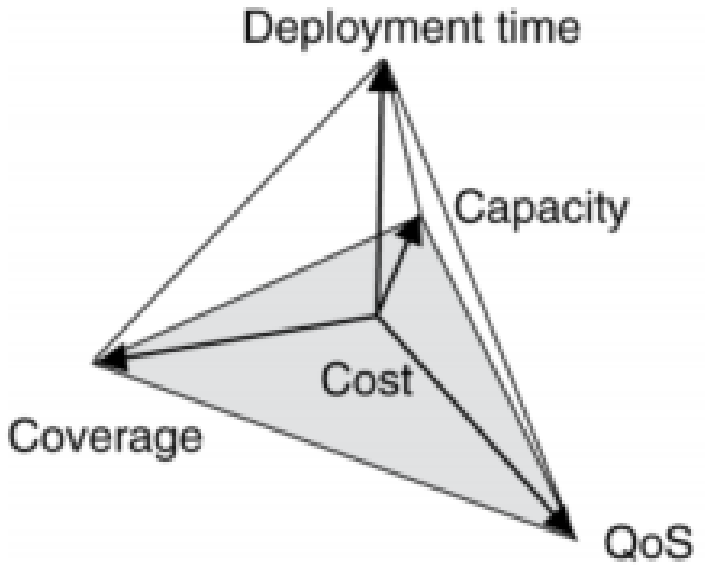
- Review
- GSM Capacity
- CDMA Capacity
- LTE Capacity

Review

Tujuan modul

- Tujuan modul Capacity Planning ini adalah:
  - Dengan bandwidth tertentu, pengaturan sumberdaya (frekuensi, waktu, daya) tertentu, teknologi nirkabel tertentu…mahasiswa dapat menghitung kapasitas trafik / throughput tiap BTS

Review: Network Design



Dimensioning

Inputs:
Coverage, Capacity & Service Requirements
Outputs:
eNodeB coverage radius and site numbers based on capacity calculation

Reverse Link Budget

Term or Factor	Given	Dense Urb.
MS TX Power (dBm) (+)	23	
MS antenna gain and body loss (+) (-)	0	
MS EIRP (dBm) (=)		23.00
Fade Margin (dB) (-)		-7.67
Soft Handoff Gain (dB) (+)		4
Receiver Interf. Margin (dB) (-)		3
Building Penetration Loss (dB) (-)		-20.00
BTS RX antenna gain (dBi) (+)		17
BTS cable loss (dB) (-)		-3
KTB (dBm/14.4 kHz)	-132.4	
BTS noise figure (dB)	5.5	
KTBF (dB)	-3.9	
BTS RX sensitivity (dBm) (=)		-139.8
Bandwidth Uplink Path Loss (dB) (=)		138.4

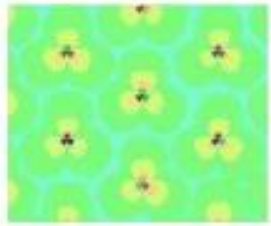
	Dense Urban	Urban
Covered Area of this type, sqkm*2	55	450
One cell's coverage in this zone, sqkm*2	1.63	4.69
# Cells required to cover zone	33.7	100.1

Pre-Planning

Inputs:
Calculated coverage radius, digital map and subscriber distribution information
Outputs:
Preliminary eNodeB numbers

Detailed Planning

Inputs:
Coverage target and site survey result
Outputs:
Actual site location and engineering parameters



Review: Network Planning

“Subscriber Side”

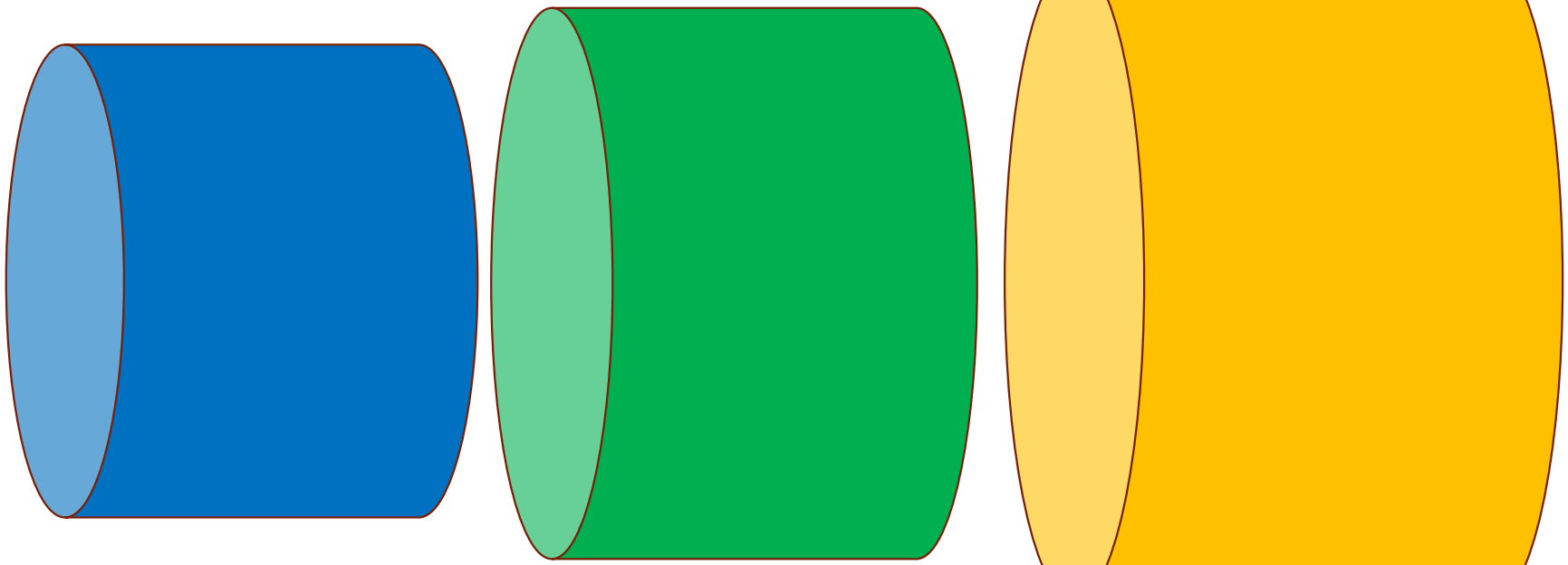
Offered Traffic
Offered Bit Quantity

“Network Side”

“Radio Access Network”

“Backhaul Network”

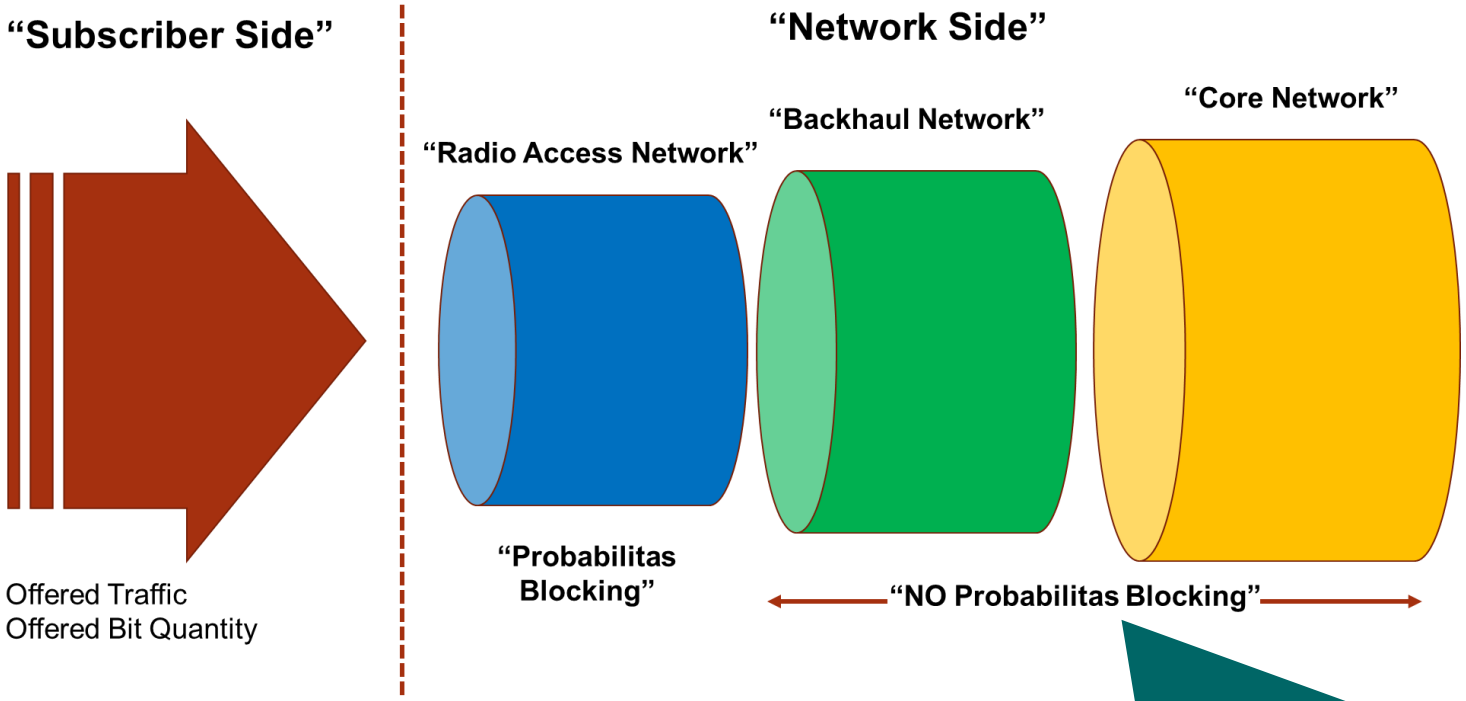
“Core Network”



“Probabilitas Blocking”

“NO Probabilitas Blocking”

Capacity Paradigm



Circuit Switched Network:

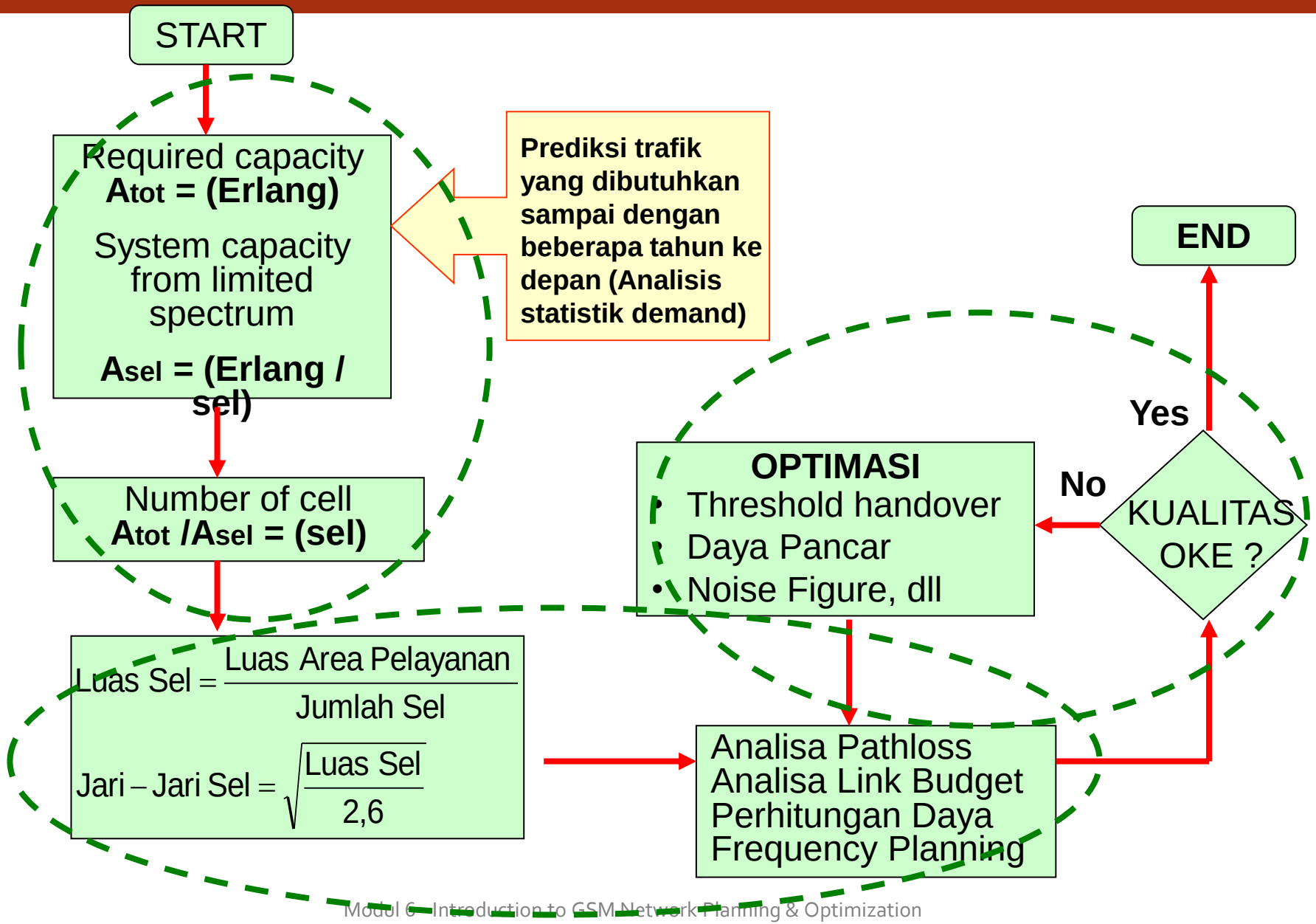
- Kapasitas Radio Access Network (RAN) direncanakan untuk mengakomodasi Offered Traffic hingga beberapa tahun kemudian pada probabilitas blocking tertentu

Packet Switched Network:

- Kapasitas Radio Access Network (RAN) direncanakan untuk mengakomodasi Offered Bit Quantity hingga beberapa tahun kemudian

- Kapasitas Backhaul dan Core Network, direncanakan untuk mengakomodasi trafik RAN hingga beberapa tahun kedepan.
- Tidak boleh ada blocking di Backhaul dan Core Network.
- Utilitas jaringan umumnya ditetapkan maksimum 70%

Concept of Capacity Approach in Network Planning



GSM Capacity

Capacity Mindset

BANDWIDTH YANG DIALOKASIKAN

STANDAR KOMUNIKASI BERGERAK SELULER

KAPASITAS TIAP SEL

(Throughput / sel)

(Erlang / sel)

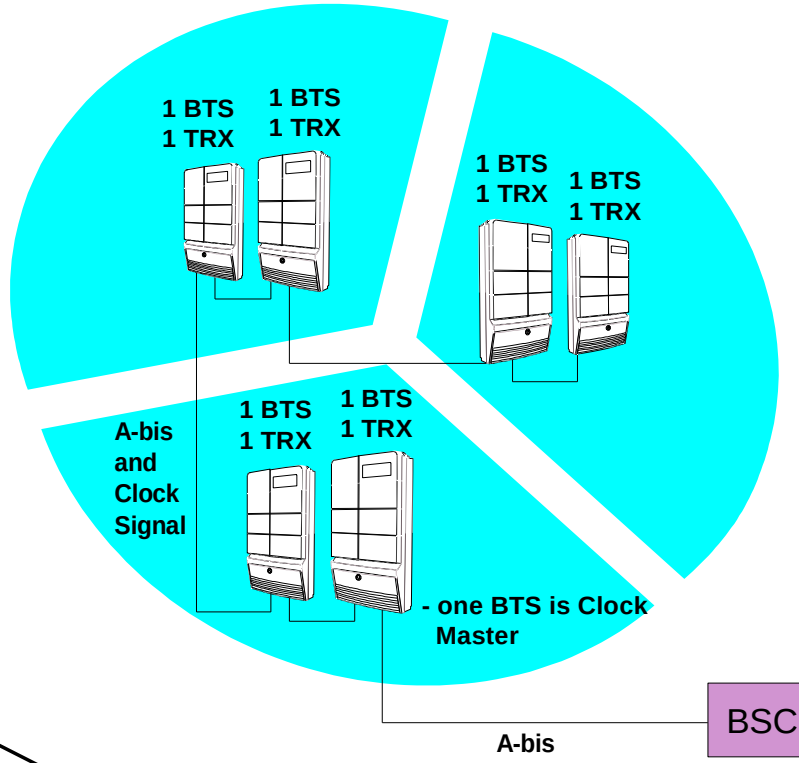
Spesifik standar:

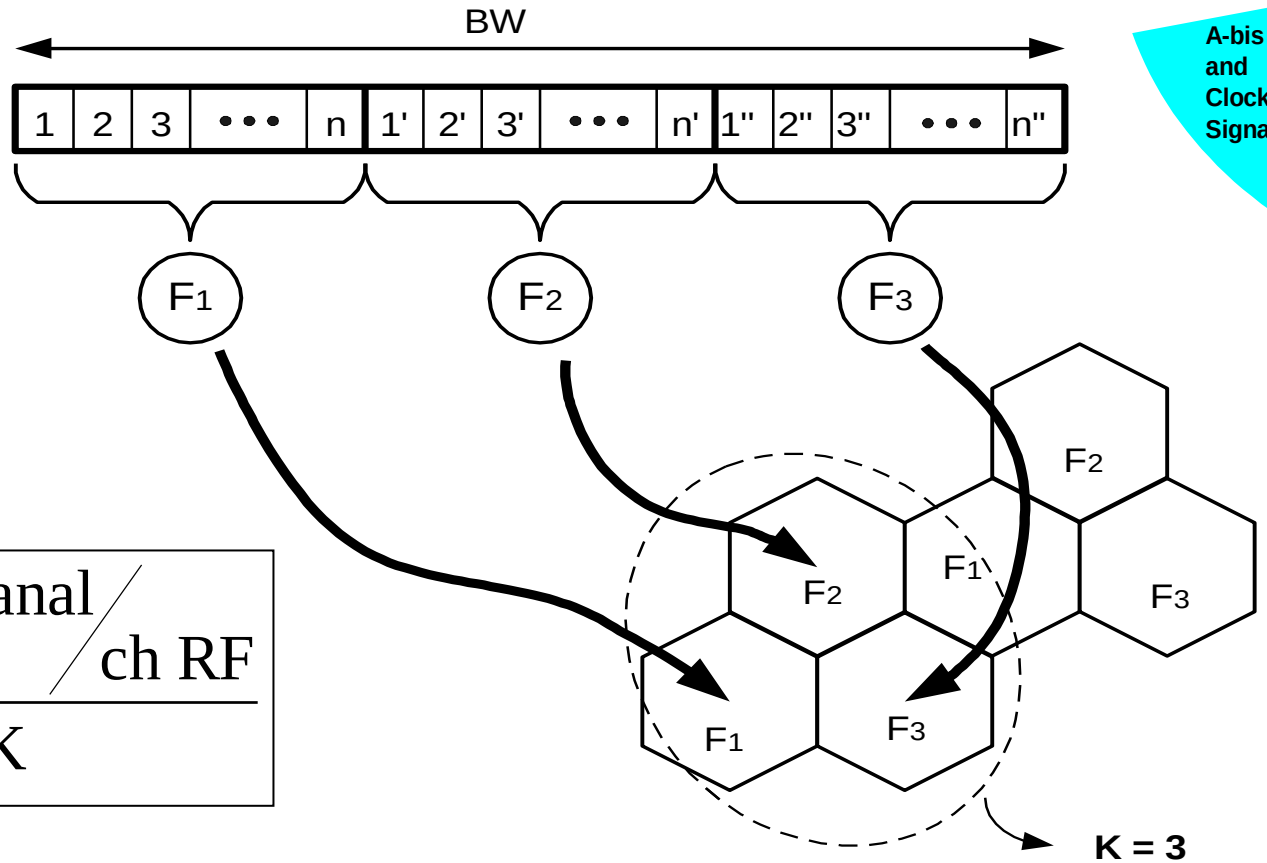
- Reuse factor
- Efisiensi spektrum
- Power transmit

$$N = \frac{BW_{Alokasi}}{BW_{ch\ RF}} \frac{\text{jumlah kanal} \,/\, \text{ch RF}}{K}$$

Review: Kapasitas Kanal Tiap Sel

OPERATOR GSM	ALOKASI FREKUENSI		
	GSM900 (MHz)	GSM1800 (MHz)	TOTAL (MHz)
TELKOMSEL	7.5	22.5	30
INDOSAT	10	20	30
XL	7.5	7.5	15
AXIS	0	15	15
THREE	0	10	10
TOTAL	**25**	**75**	**100**

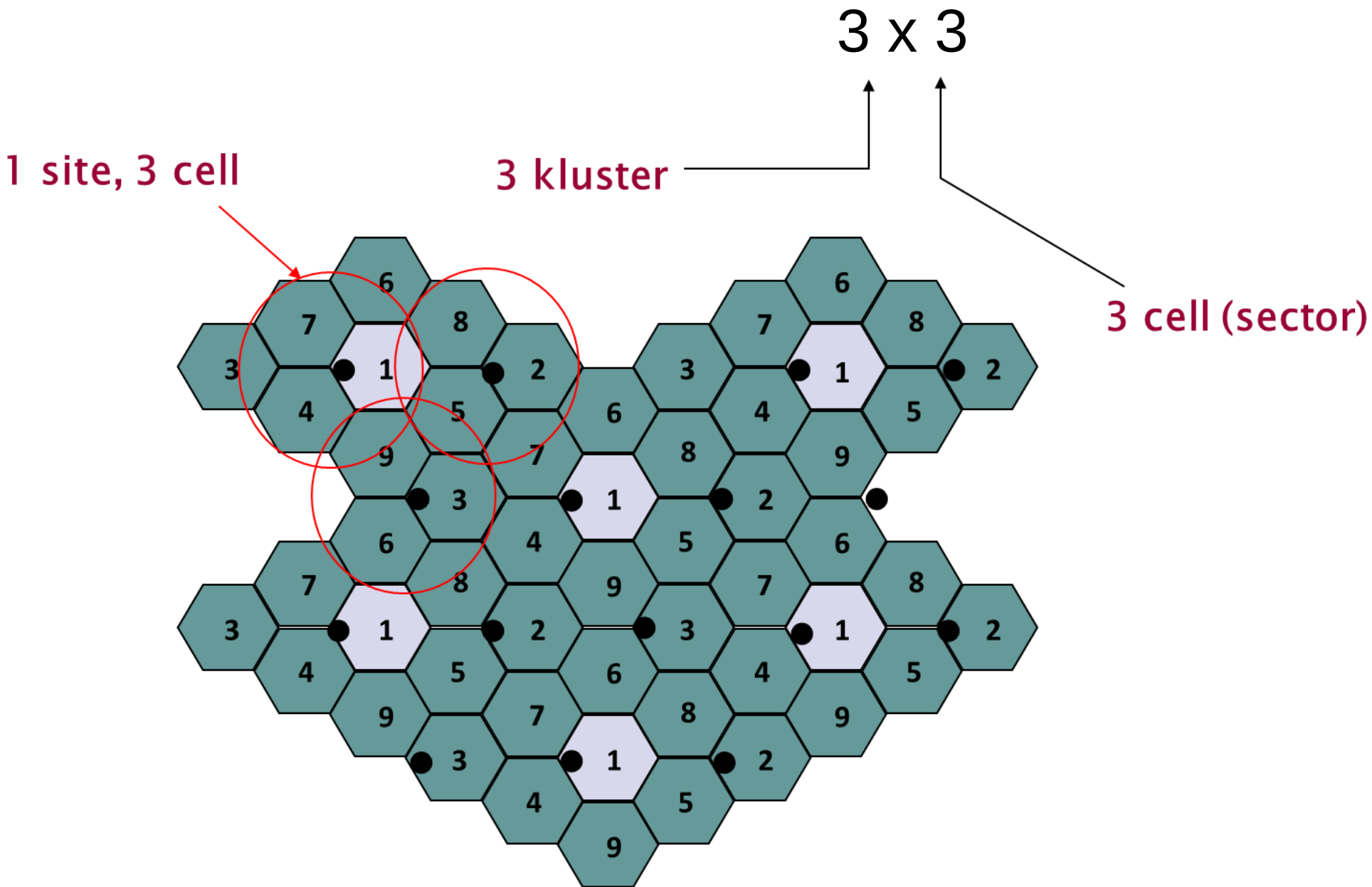




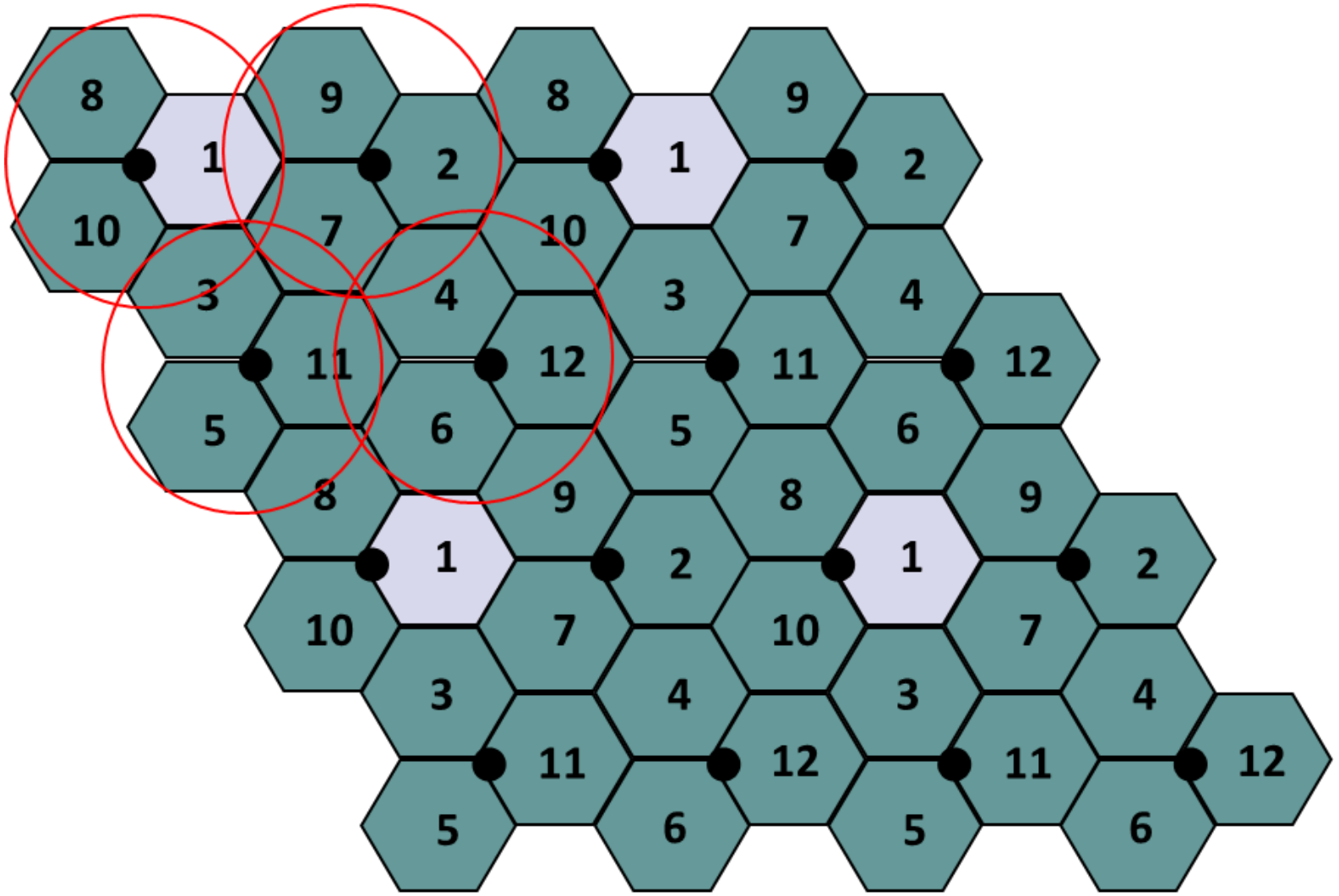
$$N = \frac{BW_{Alokasi}}{BW_{ch\ RF}} \frac{jumlah\ kanal / ch\ RF}{K}$$

Dapat disimpulkan, jumlah frekuensi carrier dalam satu sel adalah **lebih dari satu buah…**

Frequency Reuse Patterns (3x3)



Frequency Reuse Patterns (4x3)



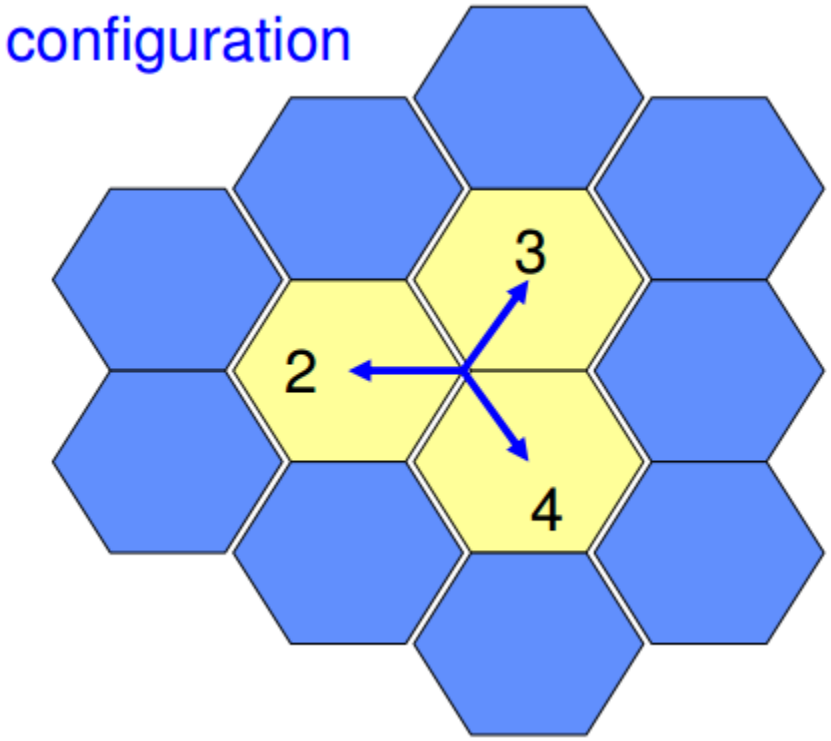
Capacity Calculations

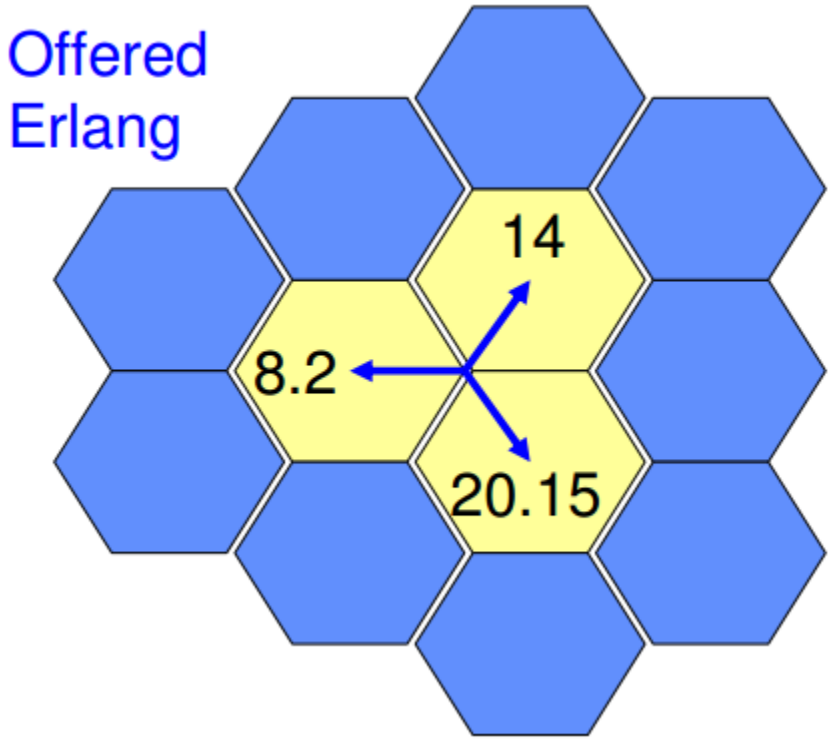
Erlang-B Table

	Blocking Probability					Blocking Probability			
Channels	1%	2%	3%	5%	Channels	1%	2%	3%	5%
1	0,01	0,02	0,03	0,05	21	12,80	14,00	14,90	16,20
2	0,15	0,22	0,28	0,38	22	13,70	14,90	15,80	17,10
3	0,46	0,60	0,72	0,90	23	14,50	15,80	16,70	18,10
4	0,87	1,09	1,26	1,52	24	15,30	16,60	17,60	19,00
5	1,36	1,66	1,88	2,22	25	16,10	17,50	18,50	20,00
6	1,91	2,28	2,54	2,96	26	17,00	18,40	19,40	20,90
7	2,50	2,95	3,25	3,75	27	17,80	19,30	20,30	21,90
8	3,13	3,63	3,99	4,54	28	18,60	20,20	21,20	22,90
9	3,78	4,34	4,75	5,37	29	19,50	21,00	22,10	23,80
10	4,46	5,08	5,53	6,22	30	20,30	21,90	23,10	24,80
11	5,16	5,84	6,33	7,08	31	21,20	22,80	24,00	25,80
12	5,88	6,61	7,14	7,95	32	22,00	23,70	24,90	26,70
13	6,61	7,40	7,97	8,83	33	22,90	24,60	25,80	27,70
14	7,35	8,20	8,80	9,73	34	23,80	25,50	26,80	28,70
15	8,11	9,01	9,65	10,60	35	24,60	26,40	27,70	29,70
16	8,88	9,83	10,50	11,50	36	25,50	27,30	28,60	30,70
17	9,65	10,70	11,40	12,50	37	26,40	28,30	29,60	31,60
18	10,40	11,50	12,20	13,40	38	27,30	29,20	30,50	32,60
19	11,20	12,30	13,10	14,30	39	28,10	30,10	31,50	33,60
20	12,00	13,20	14,00	15,20	40	29,00	31,00	32,40	34,60

Contoh Perhitungan Kapasitas Erlang

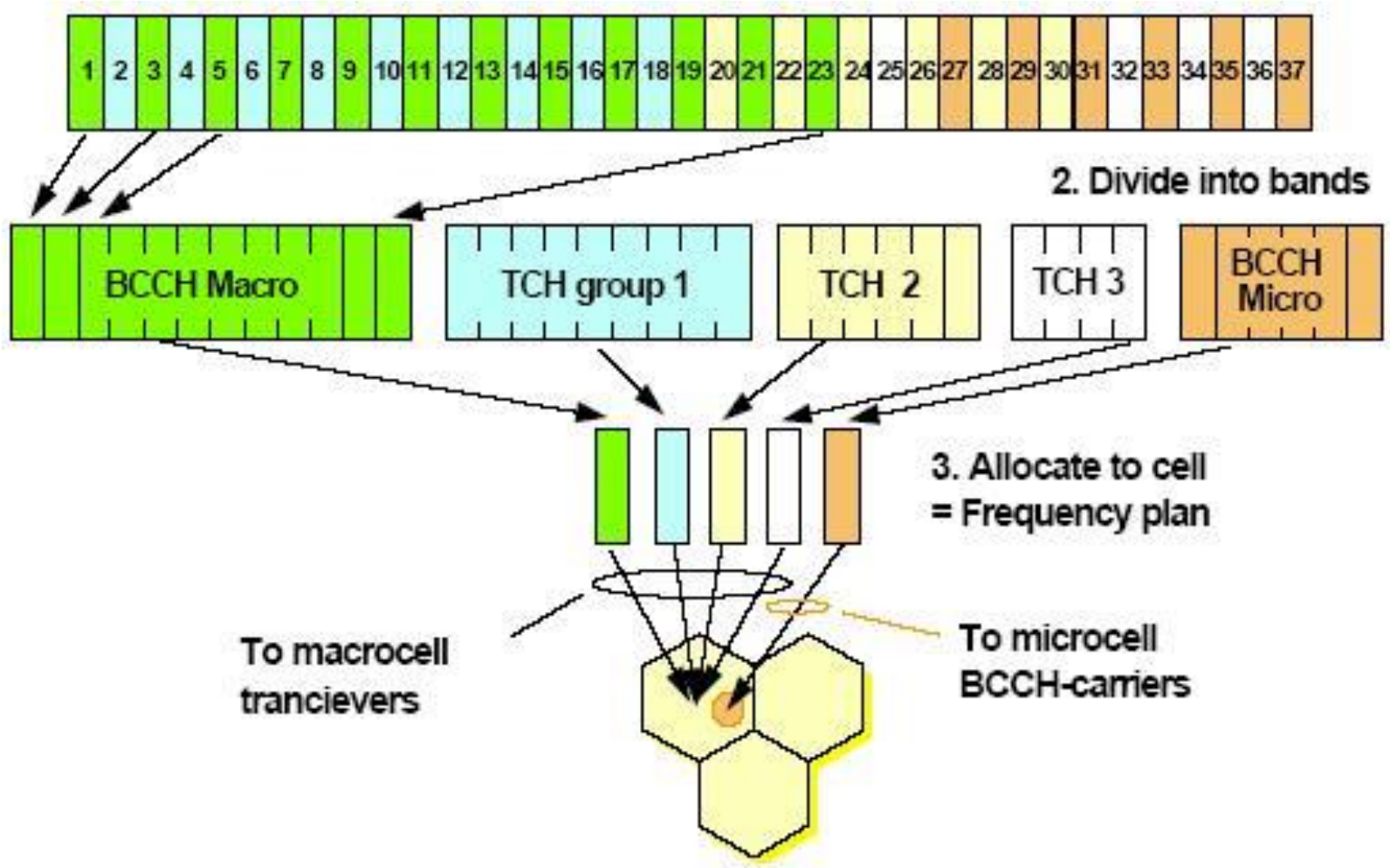
Sebuah site, dengan konfigurasi BTS (2/3/4)





How To Plan Frequency

Basic concepts → MRP = Multiple Reuse Pattern



Frequency Plan: Multiple Re-Use-Factor

- Capacity increase with multiple RuFs
  - e.g. network with 300 cells
  - Bandwidth : 8 MHz (40 radio channels)
- Single RuF =12
  - NW capacity = 40/12 * 300 = 1000 TRX
- Multiple RuF
  - BCCH layer: re-use =14, (14 frq.)
  - Normal TCH: re-use =10, (20 frq.)
  - Tight TCH layer: re-use = 6, (6 frq.)
  - NW cap. = (1 +2 +1)* 300 = 1200 TRX

GSM Channel Numbering

- GSM900

  $F_U(n) = 890 + 0.2 \times n$ (MHz)

  $F_D(n) = F_u(n) + 45$ (MHz) $1 \leq n \leq 124$

- E-GSM900

  $F_U(n) = 890 + 0.2 \times (n-1024)$ (MHz) $974 \leq n \leq 1023$

  $F_D(n) = F_u(n) + 45$ (MHz)

  n is called *Absolutely Radio Frequency Channel Number* (ARFCN)

- GSM1800

  $F_u(n) = 1710.2 + 0.2 \times (n-512)$ (MHz)

  $F_D(n) = F_U(n) + 95$ (MHz) $512 \leq n \leq 885$

  374 channels

Definition of C/I and C/A

- Co-channel Interference (C/I)
  - C/I refers to the interference of another cell using the same frequency to the current cell. The ratio of carrier to interference is called C/I.
  - GSM specification regulates that C/I _>9dB. In implementing, it requires **C/I>12dB**.
- Adjacent channel interference (C/A)
  - C/A refers to interference of adjacent cell to the current cell. The ratio is called C/A.
  - The GSM specification regulates that **C/A>-9dB**.

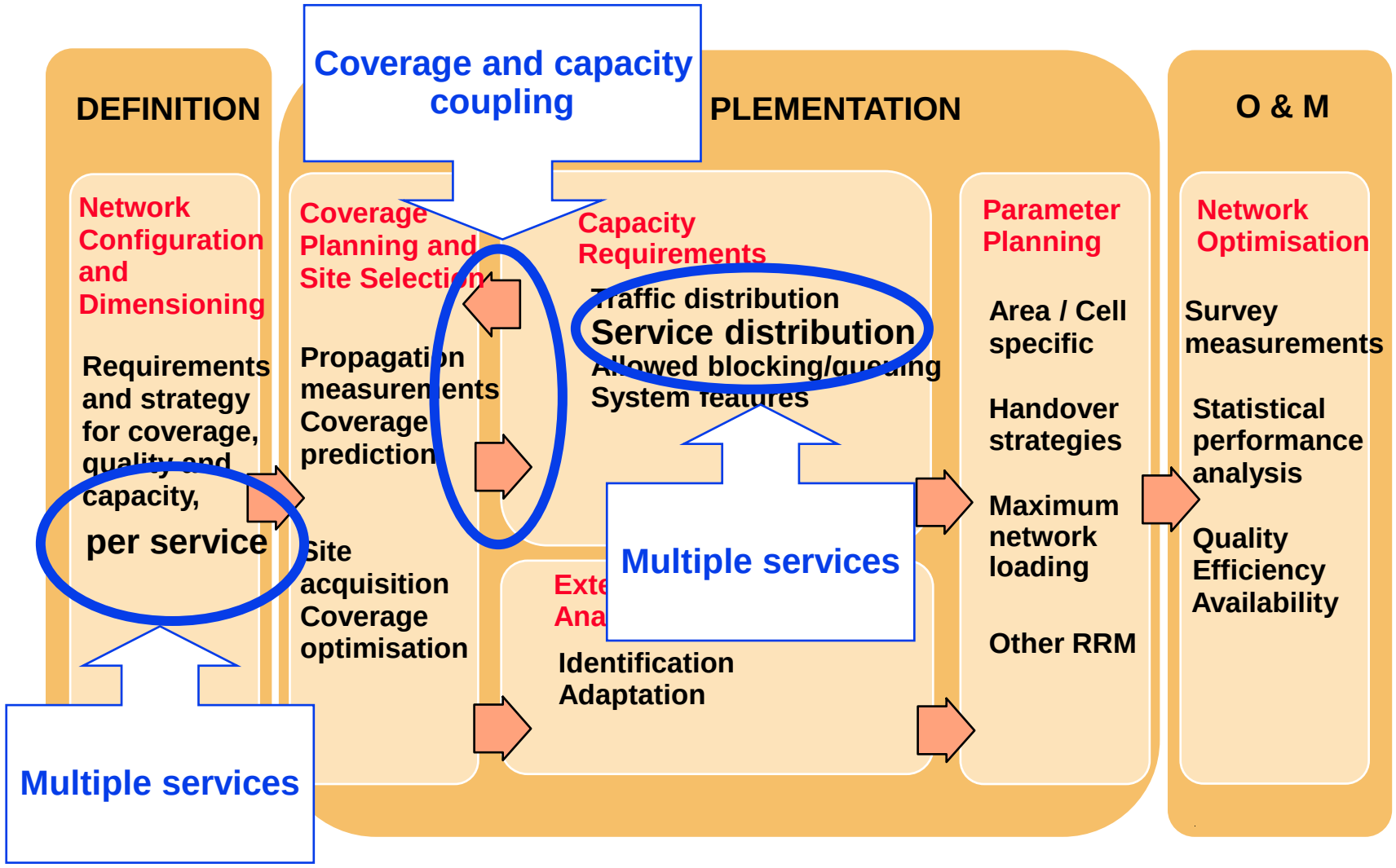
Maximum capacity

- example how to calculate the maximum capacity

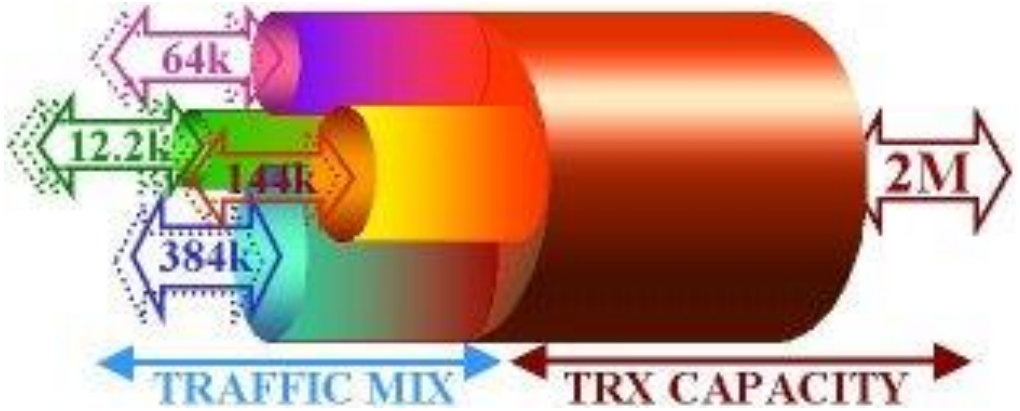
Grade of Service		0.02	2 %
Spectrum		36	7.2 MHz
Cell Range		0.5	km
Reuse factor	9	12	18
Carriers/Cell	4	3	2
Erlangs/3cells	65.78	44.67	27.02
Coverage Area/site	0.4875		
Erlangs/km2	134.93	91.64	55.42

WCDMA Capacity

New issues in WCDMA planning process



Introduction: Gambaran Mix Traffic

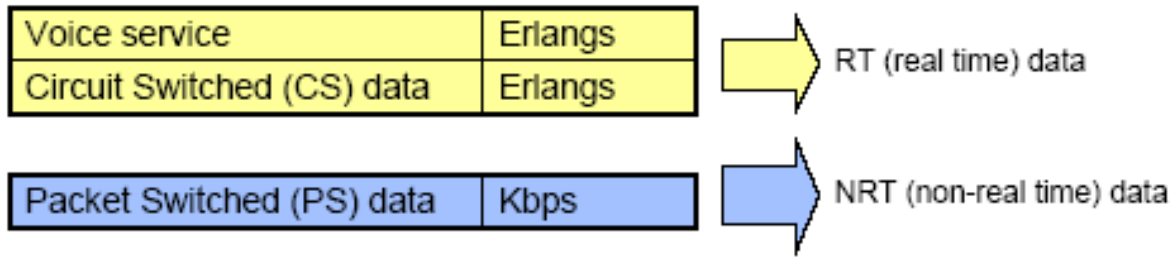


Selama jam sibuk rata-rata user melakukan download **10 Mbit** dengan kecepatan 384 kbits/s, **2 Mbit dgn kecepatan** 144 kbits/s dan membuat satu kali panggilan suara **60-second** voice call. Data ditransmisikan rata-rata 1,1 kali karena kondisi jaringan.

Service Rate	Average Rate
(10000 kbit / 3600 sec) x 1.1	3.06 kbits/s
(2000 kbit / 3600 sec) x 1.1	0.61 kbits/s
(60sec x 12.2 kbit/s) / 3600 sec	0.20 kbits/s
Total	**3.87 kbits/s / user / busy hour**

Capacity Related Input

- The number of subscribers, user profile and spectrum available are the main requirements for capacity dimensioning
- Traffic data:
  - Voice :
    - Erlang per subscriber during busy hour of the network
    - Codec bit rate, Voice activity
  - RT data :
    - Erlang per subscriber during busy hour of the network
    - Service bit rates
  - NRT data :
    - Average throughput (kbps) subscriber during busy hour of the network
    - Target bit rates
- Busy hour traffic figures for each service are broken down into traffic per subscriber (separate for uplink and downlink)
- Subscriber evolution forecast is also needed



Capacity Related Input

The traffic figures are broken down into traffic per subscriber and busy hour for each service, separately for uplink and downlink

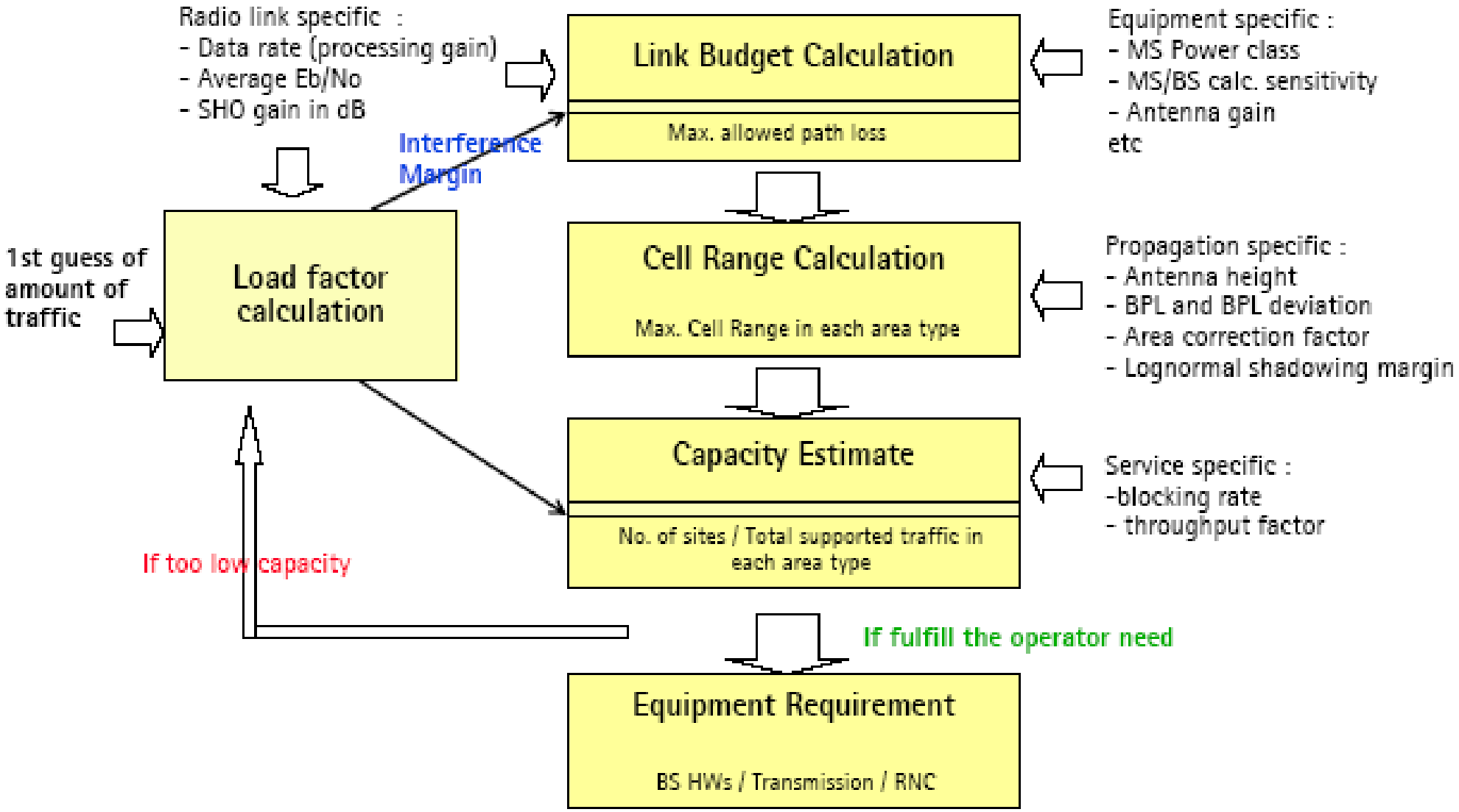
BH traffic/subs DL

		Low asymmetry	Medium asymmetry	High asymmetry	
Speech	12,2 kbit/s	22,383	22,383	22,383	mErl
switched data	RT 14 kbit/s	0,390	0,390	0,390	mErl
simple messaging	NRT 144 kbit/s	0,004	0,007	0,010	kbit/s
medium multimedia	NRT 384 kbit/s	0,102	0,137	0,246	kbit/s
Interactive multimedia	RT 64 kbit/s	0,028	0,142	0,427	mErl

BH traffic/subs UL

		Low asymmetry	Medium asymmetry	High asymmetry	
Speech	12,2 kbit/s	22,383	22,383	22,383	mErl
switched data	RT 14 kbit/s	0,390	0,390	0,390	mErl
simple messaging	NRT 144 kbit/s	0,004	0,007	0,010	kbit/s
medium multimedia	NRT 384 kbit/s	0,003	0,004	0,006	kbit/s
interactive multimedia	RT 64 kbit/s	0,028	0,142	0,427	mErl

WCDMA RF Dimensioning Process Flow



Konsep Kapasitas CDMA: Reverse pole capacity

$$\text{Reverse Pole Capacity} = \text{N} = \frac{\text{W/R}}{\left[\frac{Eb}{No + Io}\right]_{adjust}} . \left(\frac{1}{1+f}\right) . \frac{1}{\rho} . G_s$$

Asumsi :

W	= bandwidth 1 kanal RF WCDMA	1228800 Hz (CDMA), 3840000 Hz (UMTS)
R	= Data rate (vocoder rate set 1-tepi sel)	9600 bps (voice CDMA), 12200 (UMTS)
f	= Rasio interferensi luar thd dalam sel	0,7
ρ	= Faktor aktivitas suara atau data	0,4 (voice)
G_s	= Gain sektorisasi	2,4

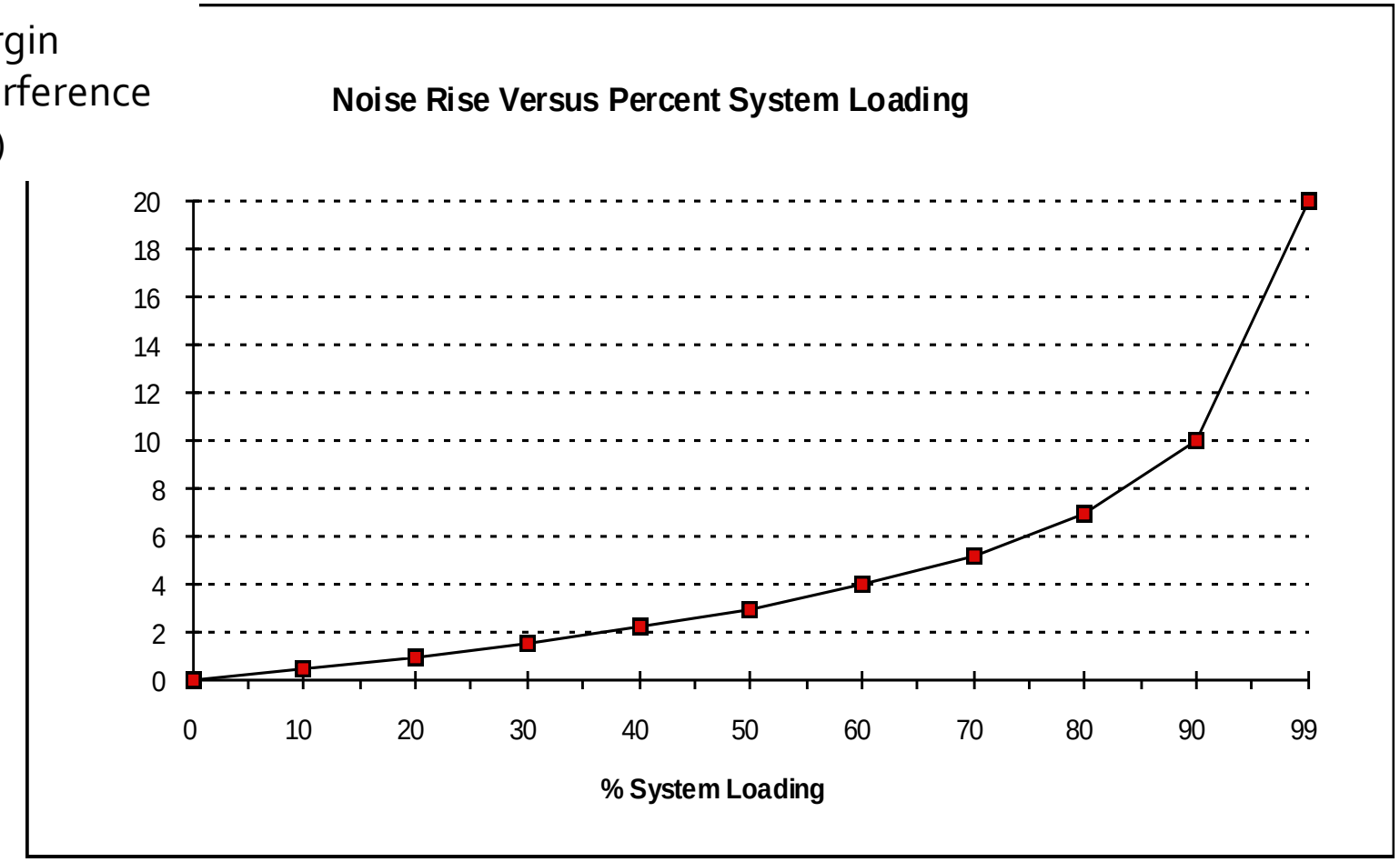
$\left[Eb/(Io+No)\right]_{adjust}$ = Perbandingan energi per-bit per total noise dan interferensi (sbg syarat kualitas di bawah kondisi power control tak sempurna) → 7,2 dB (mobile) , atau 5 dB (fixed communication)

Contoh Perhitungan Reverse pole capacity (cont'd)

- Untuk asumsi-asumsi yang diberikan dan loading factor 75%, kapasitas **pole reverse ≈ 22 kanal/sektor (Utk GoS 2% → 14,9 Erlang per-sektor)**
- **Implementasi untuk FWA ,** Eb/[Io+No] dapat diturunkan menuju 4-5 dB → kapasitas lebih besar → terhitung sekitar 35 kanal tiap sektor

Pengaruh Cell Loading

Margin Interference (dB)



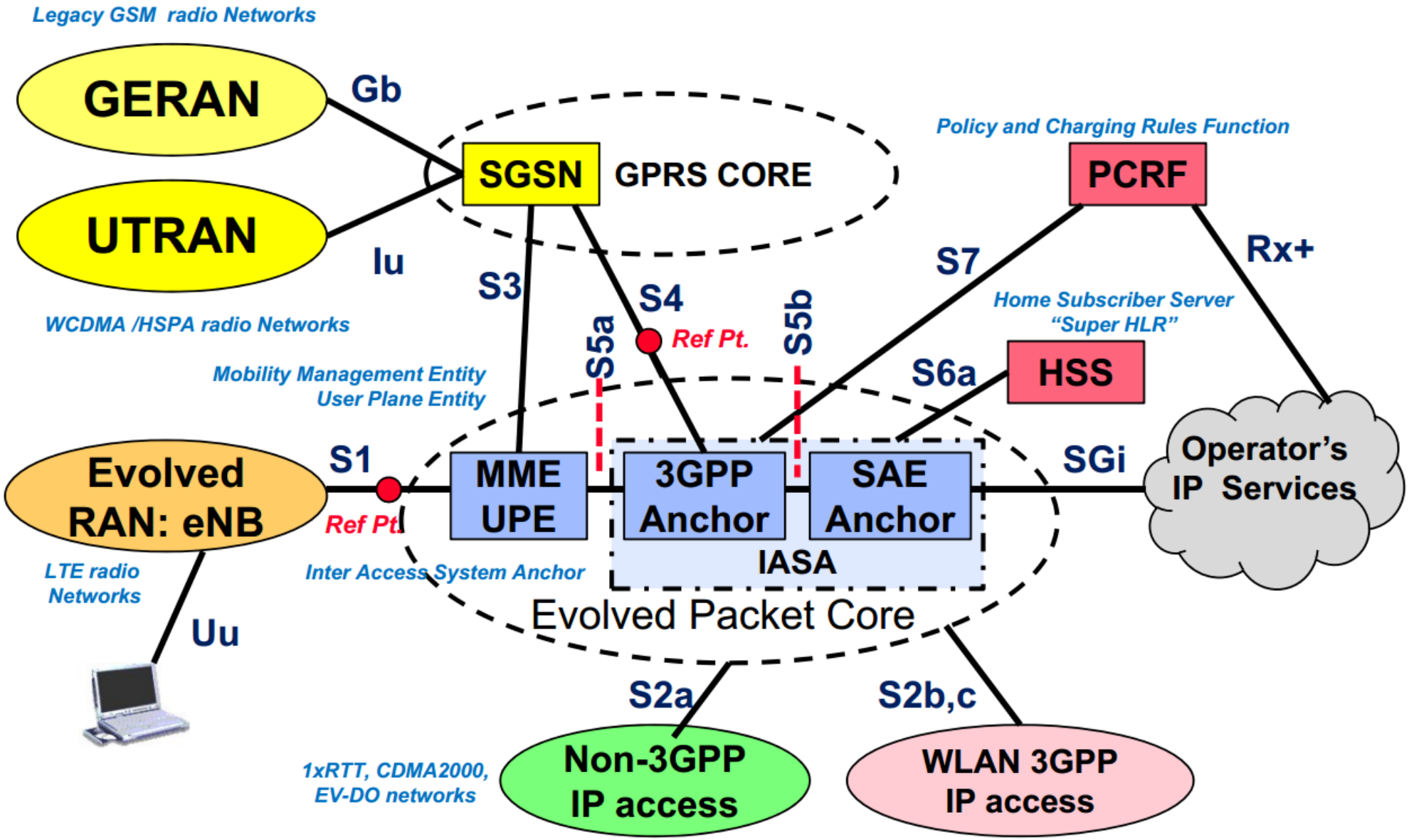
2. Isu-Isu Yang Mempengaruhi Kapasitas CDMA

- **Loading factor** adalah kapasitas yang terpakai pada CDMA dibandingkan terhadap kapasitas maksimumnya (pole capacity)
- Semakin besar loading factor → Kapasitas sel naik (**positif**) → noise latar naik → memerlukan margin interferensi semakin besar dalam perhitungan Link Budget → Perlu daya sel besar → Interferensi bagi sel lain → Kapasitas sel lain turun (**negatif**)
- Dalam perencanaan, umumnya diasumsikan loading factor 60% - 75%

Trade off

LTE Capacity

Review: LTE Network Elements & Interfaces



LTE Backhaul Interfaces

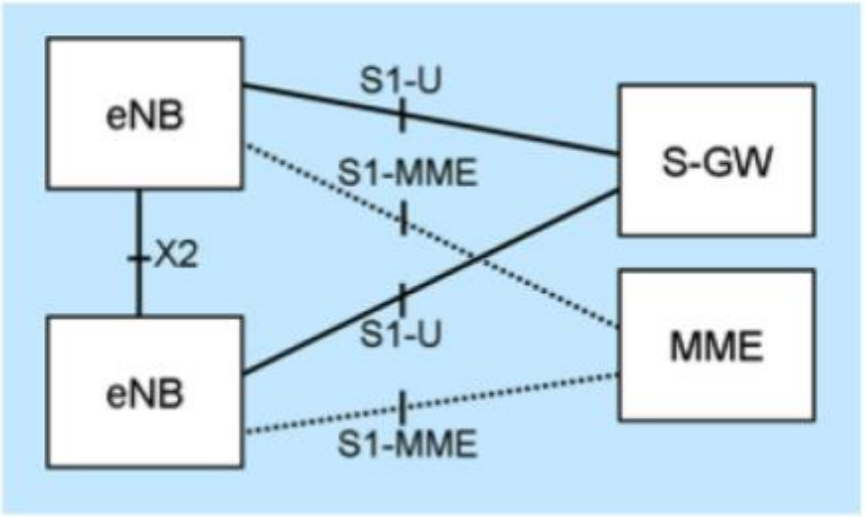
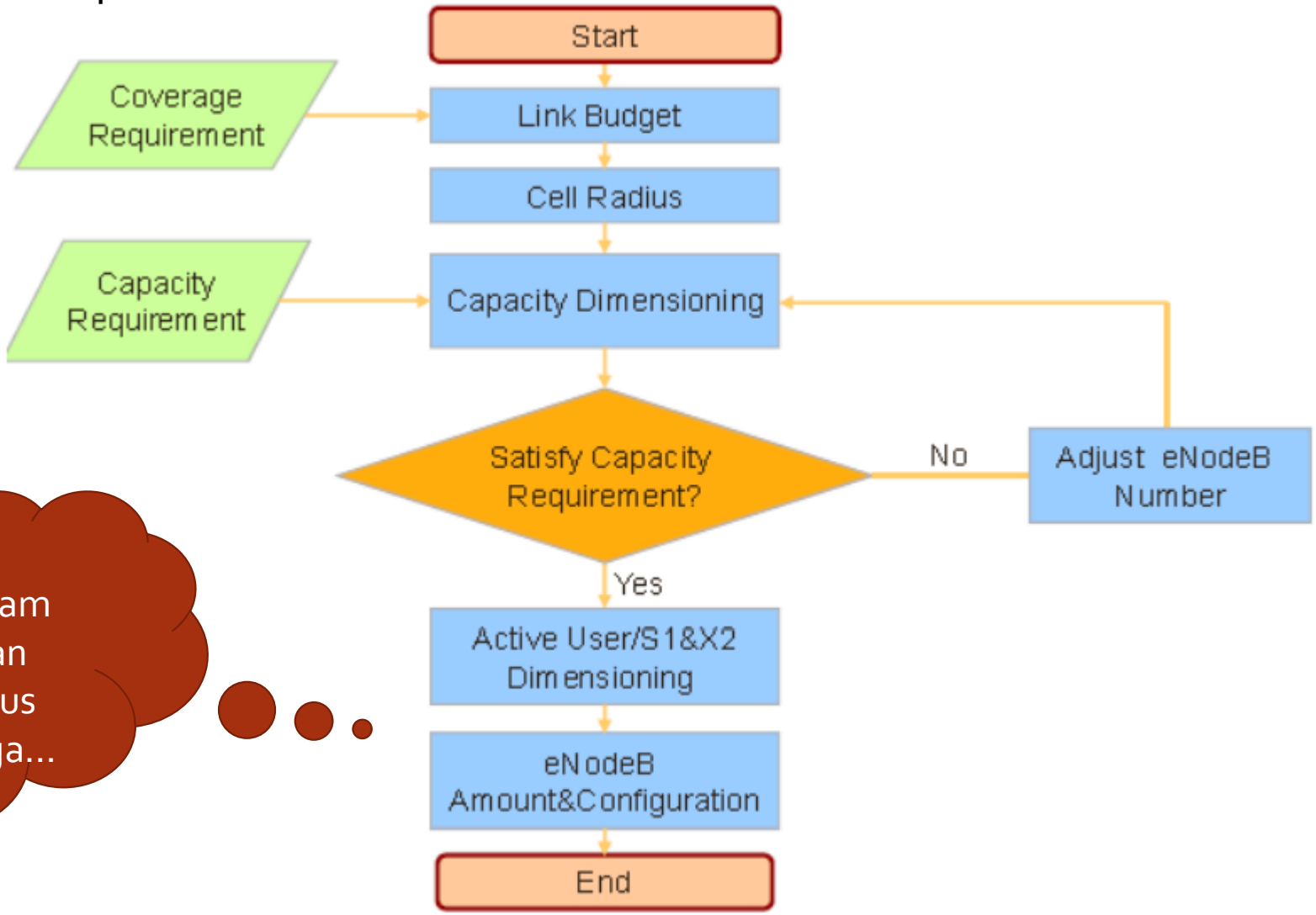


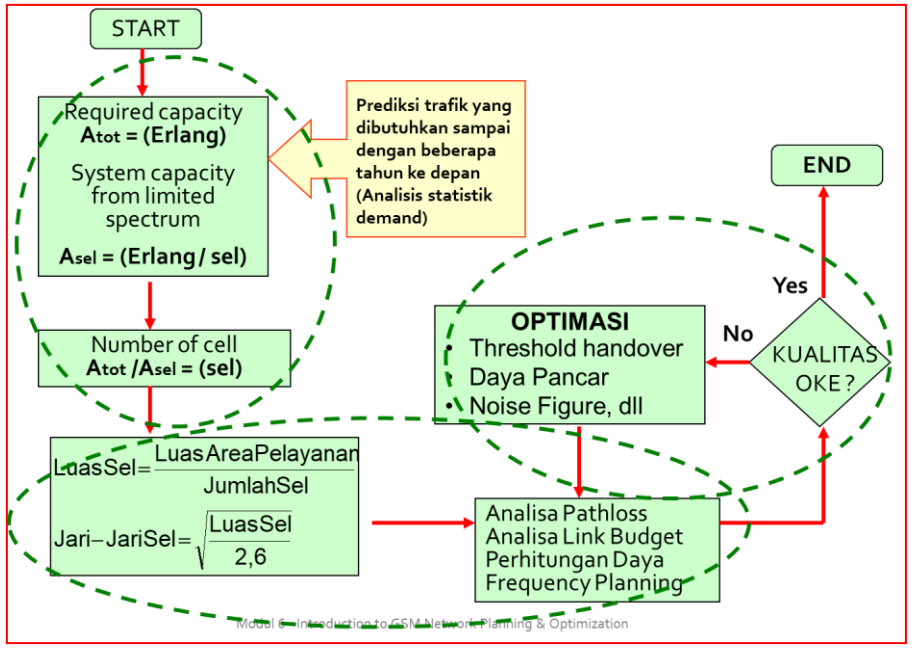
Figure 2: LTE backhaul network interfaces

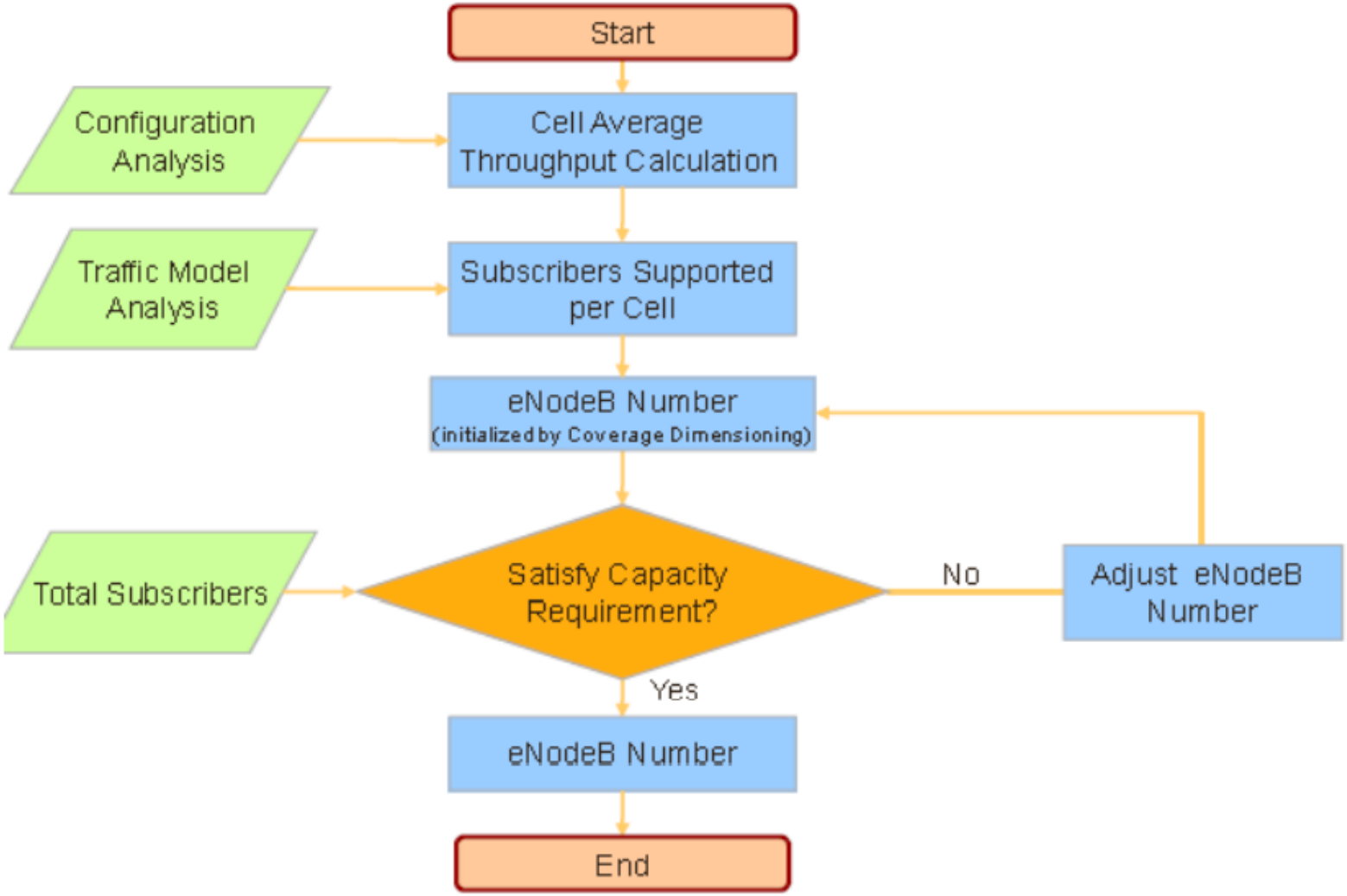
Kombinasi pendekatan coverage & kapasitas…



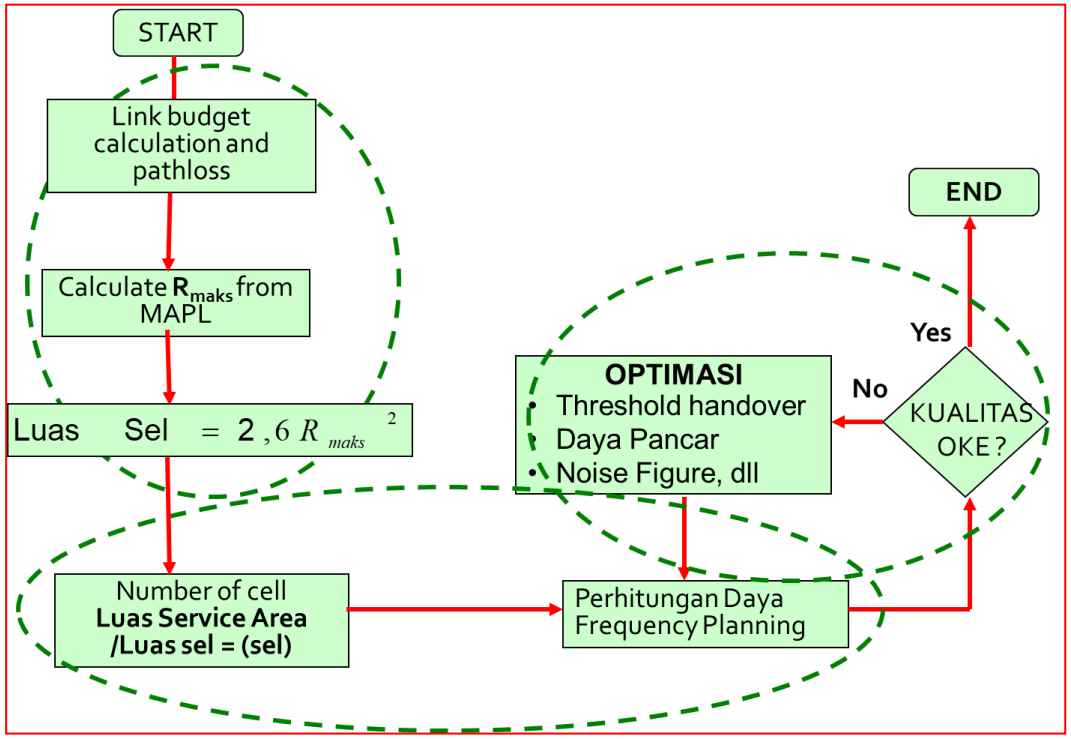
Kapasitas backhaul dalam perencanaan lengkap harus dilakukan juga…

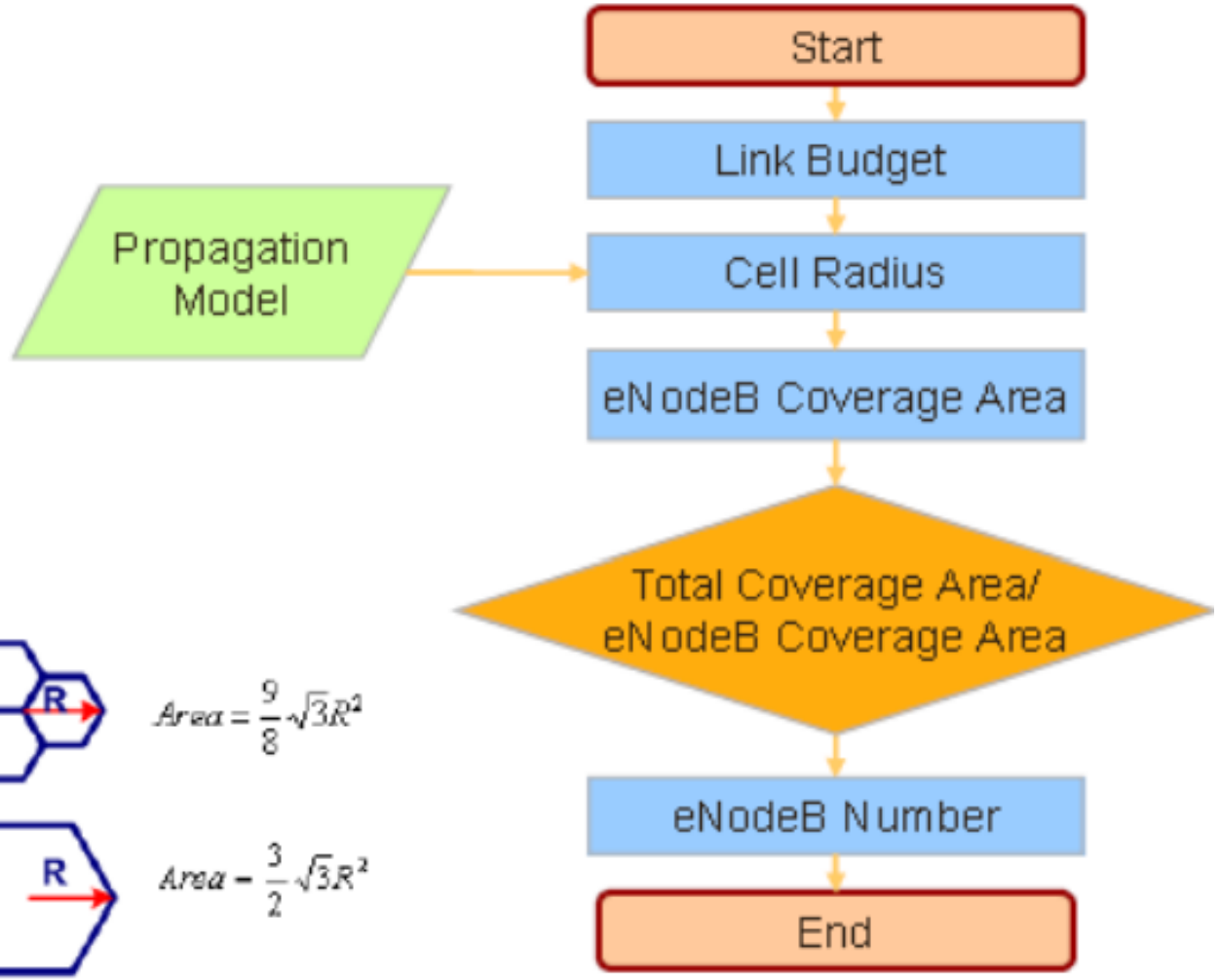
Capacity Approach Network Planning



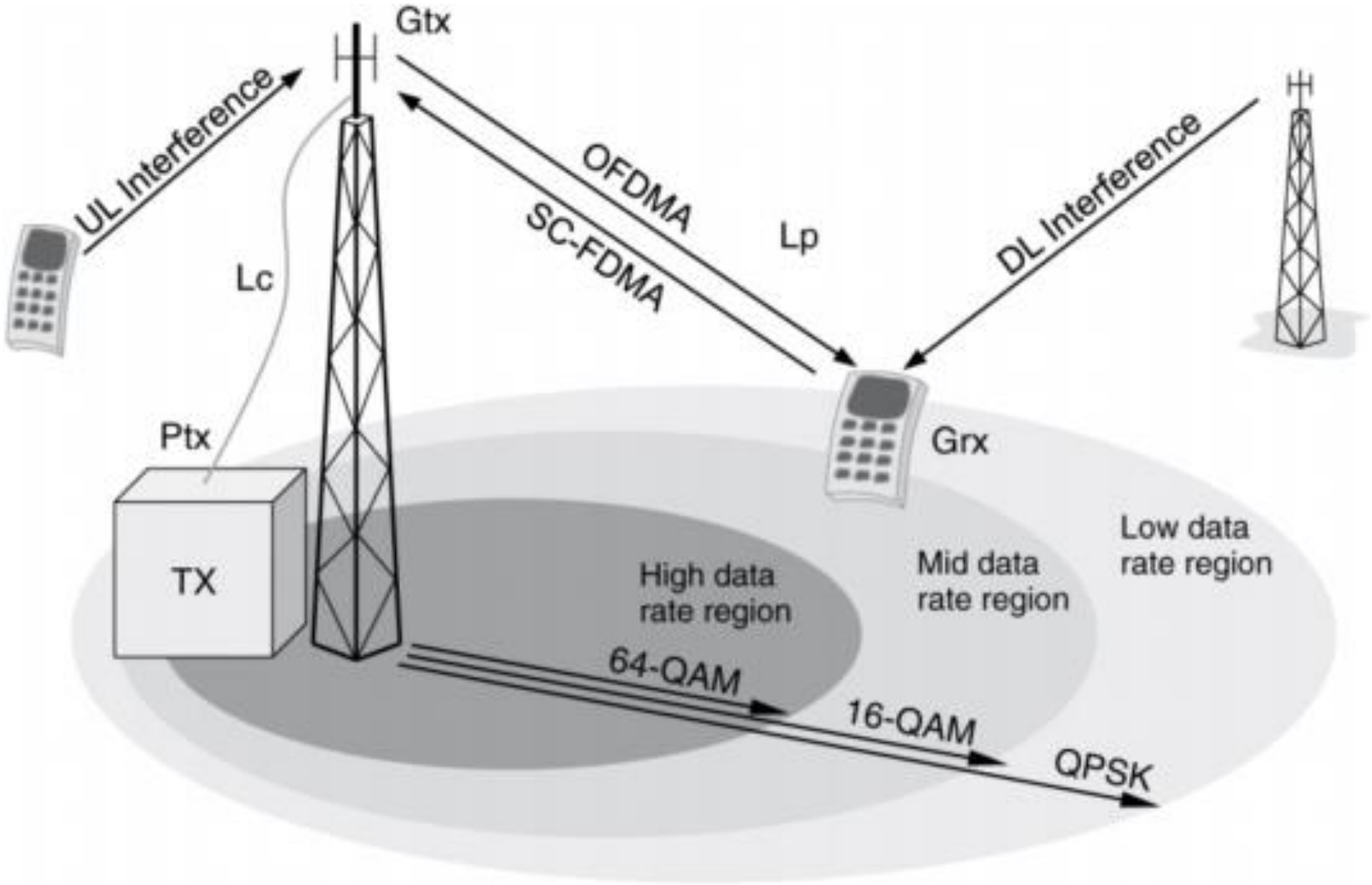


Coverage Approach Network Planning





LTE Coverage

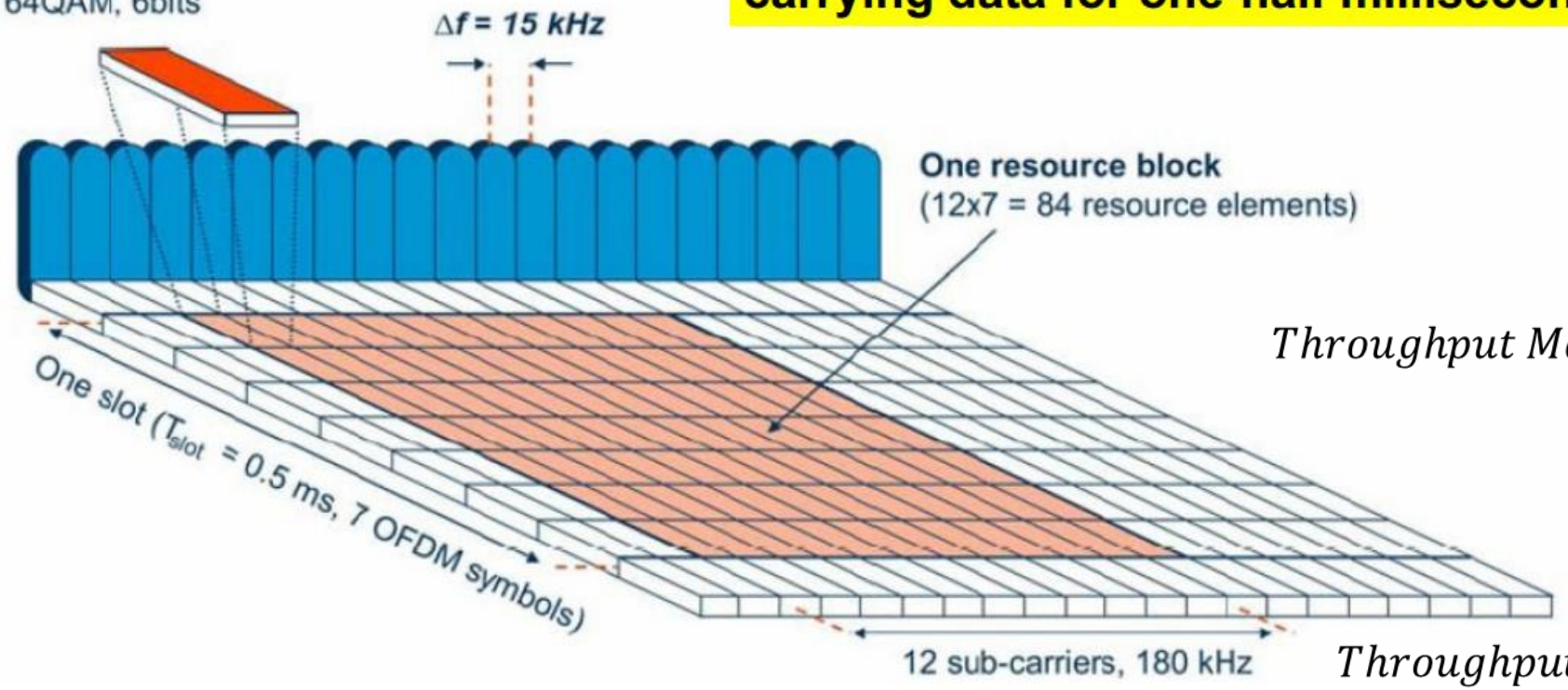


Kapasitas LTE

Signal Bandwidth, MHz.	1.4	1.6	3	3.2	5	10	15	20
Number of Resource Blocks	6	7	15	16	25	50	75	100

One resource element
QPSK, 2bits
16QAM, 4bits
64QAM, 6bits

A Resource Block is 12 subcarriers carrying data for one-half millisecond.



Untuk BW 20 MHz, semua resource element menggunakan 64 QAM (6 bit/RE)

$$Throughput\ Maksimum = \frac{100 \times 7 \times 12 \times 6\ bit}{0.5 \times 10^{-3}}$$
$$= \mathbf{100.8\ Mbps}$$

$$Throughput\ Minimum = \frac{100 \times 7 \times 12 \times 2\ bit}{0.5 \times 10^{-3}}$$
$$= \mathbf{33.6\ Mbps}$$

Physical resource block parameters

Configuration		N_{BW}^{BR}	N_{symb}^{DL} Frame structure type 1
Normal cyclic prefix	Δf = 15 kHz	12	7
Extended cyclic prefix	Δf = 15 kHz		6
	Δf = 7.5 kHz	24	3

Untuk BW 20 MHz, semua resource element menggunakan QPSK(2 bit/RE)

LTE Average Throughput

LTE 2600MHz Cell Average Throughput with different bandwidth

Frequency	Bandwidth	Scenario	Cell Average Throughput		Peak Throughput (Multi-users)	
			DL(Mbps)	UL(Mbps)	DL(Mbps)	UL(Mbps)
2600MHz	5MHz	Urban	8.173	4.715	43	39
		Suburban	6.266	3.342	43	39
	10MHz	Urban	16.918	9.761	86	55
		Suburban	12.971	6.918	86	55
	15MHz	Urban	25.546	14.739	129	126
		Suburban	19.587	10.446	129	126
	20MHz	Urban	34.344	19.814	172	165
		Suburban	26.332	14.044	172	165

Capacity comparison with different frequency band

LTE Cell Average Throughput (Urban)			
Frequency Band (MHz)	Bandwidth (MHz)	DL (Mbps)	UL (Mbps)
2600	20	34.344	19.814
1800	20	34.719	21.675
800	20	35.218	24.704

Practical Estimate of LTE Sector Throughput

Data Rate Down/Up [Mbps] vs. Distance from Cell Center			
Channel Bandwidth	Close	Medium	Far
5Mhz	17 / 5.6	11 / 3.7	5.6 / 1.8
(FDD typical) 10MHz	43 / 14.4	28 / 9.5	14 / 4.8
20MHz	85 / 28	56 / 18	28 / 9.5

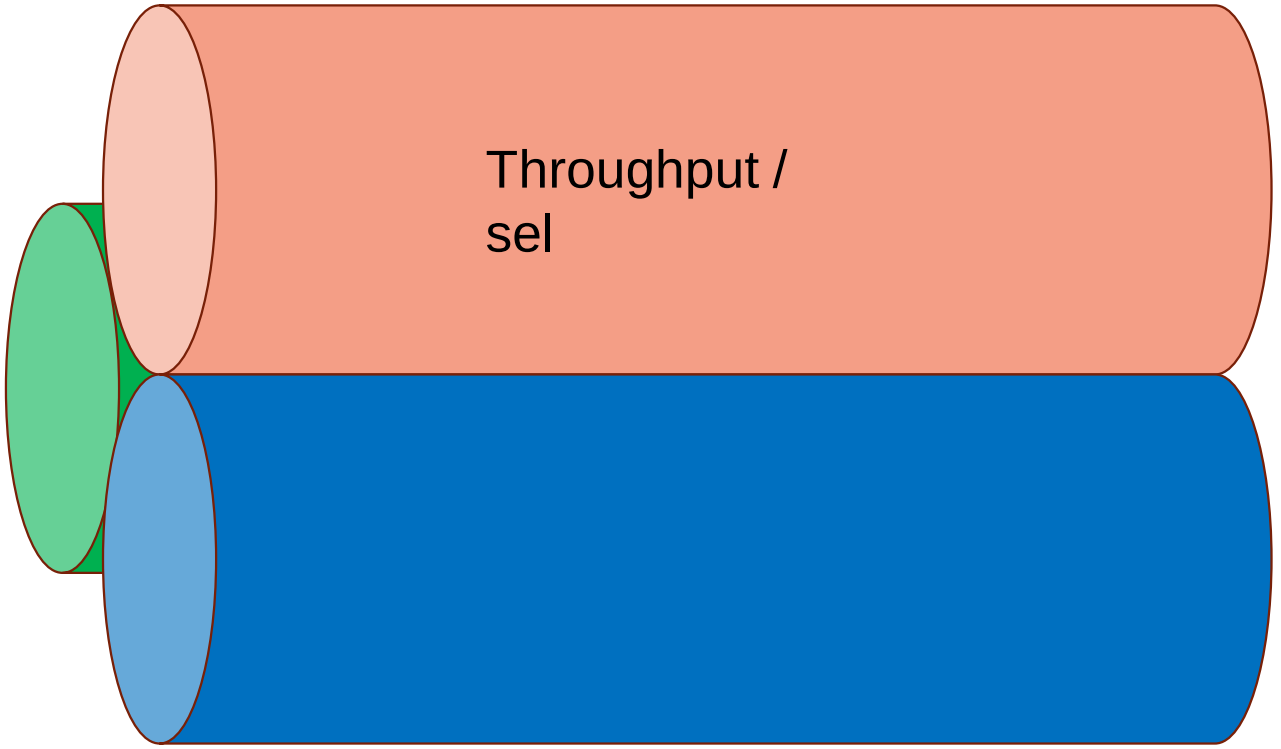
Teoritis 100 Mbps (Downlink)

Capacity Approach based Dimensioning

Carilah demand trafik subscriber di wilayah perencanaan

Carilah kapasitas network LTE, jika alokasi BW = 20 MHz ??

Hitungan Praktis:
Jumlah_potensi_subscriber
x
Busy_Hour_Throughput/ subscriber



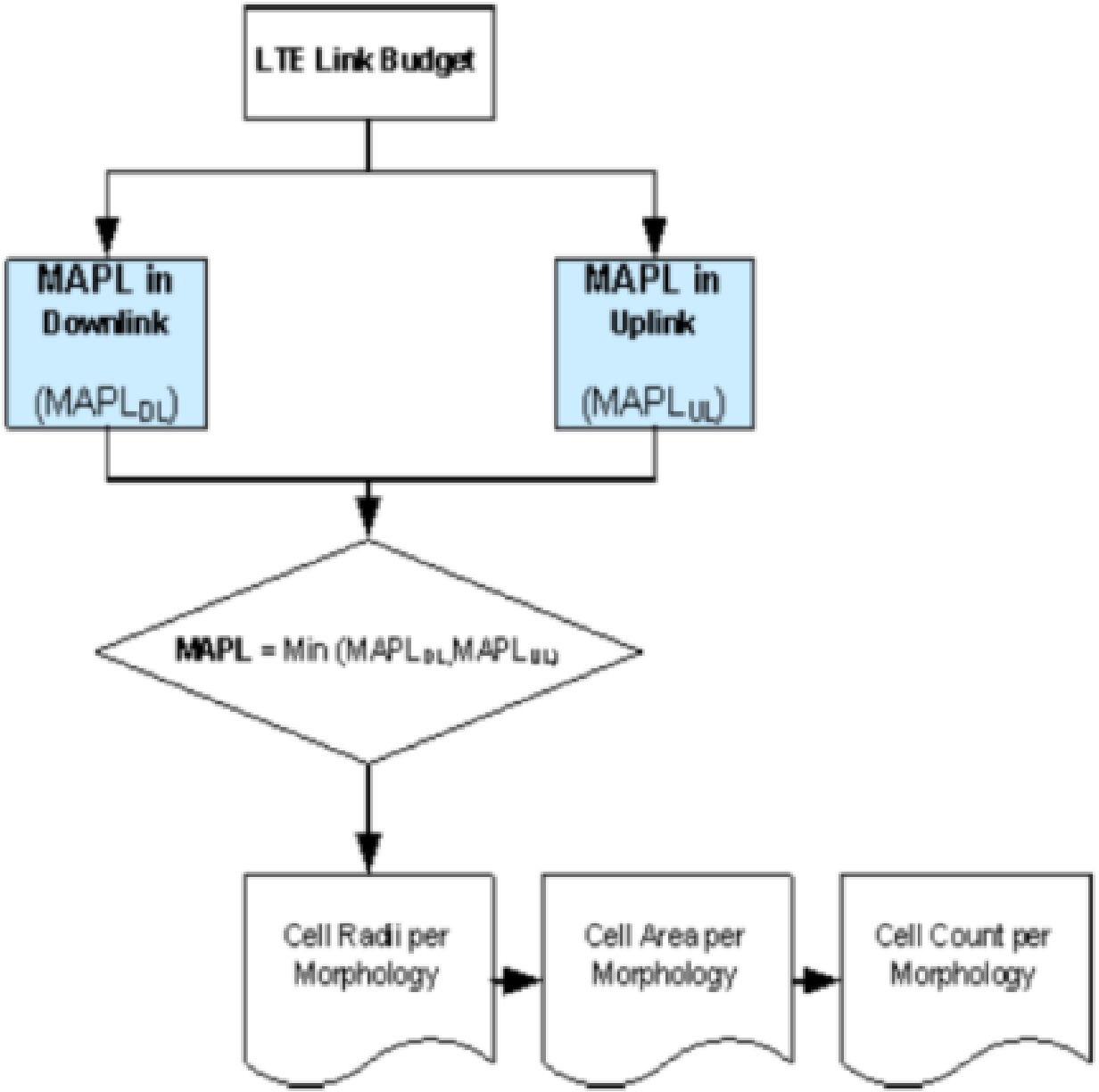
$$Jumlah\ sel = \frac{Demand\ troughput\ \ total}{Throughput_{/sel}}$$

Contoh Analisis Model Trafik Pelanggan di LTE

Traffic Parameters	UL				DL			
	Bearer Rate (Kbps)	PPP Session Time(s)	PPP Session Duty Ratio	BLER	Bearer Rate (Kbps)	PPP Session Time(s)	PPP Session Duty Ratio	BLER
VoIP	26.90	108	0.6	1%	26.90	108	0.6	1%
Video Phone	62.53	36	1	1%	62.53	36	1	1%
Video Conference	62.53	1800	1	1%	62.53	1800	1	1%
IMS Signalling	15.63	7	0.2	1%	15.63	7	0.2	1%
Web Browsing	62.53	1800	0.05	1%	250.11	1800	0.05	1%
File Transfer	140.69	600	1	1%	750.34	600	1	1%
P2P file sharing	250.11	1200	1	1%	750.34	1200	1	1%

User Behavior	Traffic Penetration Ratio	BHSA	Busy Hour Throughput Per User (bps)	
			UL	DL
Video Conference	0.00%	0.2	6316	6316
IMS Signalling	0.00%	5	31	31
Web Browsing	100.00%	0.4	632	2526
File Transfer	20.00%	0.2	4737	25264
Email	10.00%	0.2	395	632
P2P file sharing	20.00%	0.4	336.85	101055
Total	-	-	8355	27853

Which Link is Limiting? Uplink dan Downlink



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