

4G LTE RADIO NETWORK PLANNING

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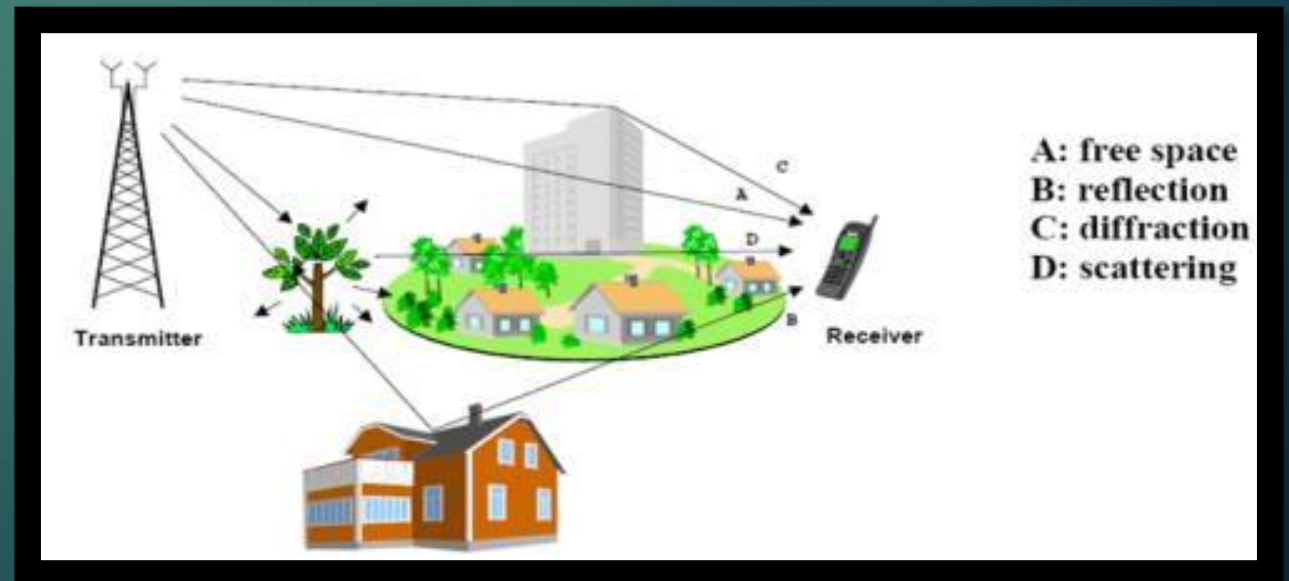
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Why pathloss and linkbudget ?

- ▶ Mendapatkan kondisi terbaik dari suatu perencanaan.
- ▶ Mudah untuk melakukan perbaikan perencanaan

PATHLOSS

- ▶ Metode yang digunakan untuk mengukur suatu loss yang disebabkan oleh cuaca, kontur tanah dll agar tidak mengganggu pemancar antar 2 buah antena yang saling berhubungan.
- ▶ Pelemahan – pelemahan sinyal bisa terjadi karena
 - a. Atenuasi
 - b. Refleksi
 - c. Difraksi
 - d. Scattering



Model Pathloss

- ▶ COST – 231
- ▶ OKUMURA-HATA
- ▶ ERCEG-GREENSTEIN (SUI)
- ▶ LONGLEY –RICE
- ▶ SAKAGAMI EXTENDED

COST – 231 HATTA

$$PL = 46,3 + 33,9 \log f_c - 13,82 \log h_b - a(hr) + (44,9 - 6,55 \log h_m) \log d + CM$$

Parameter	Notasi	Spesifikasi
Frekuensi Pembawa	f_c	1500 – 2000 Mhz
Tinggi Antenna BTS	h_b	4-50 m
Tinggi Antena MS	h_m	1-3 m
Jarak BTS dengan MS	D	0,02 – 5 km

$$a(hr) = (1,1 \log (f) - 0,7) h_b - (1,56 \log 9f) - 0,8) \quad ; \text{ Small area}$$
$$a(hr) = 3,2 (\log 11,75 h_b)^2 - 1,1 \text{ dB} \quad ; \text{ Large Area}$$
$$CM = 0 \quad ; \text{ Small Area}$$
$$CM = 3 \quad ; \text{ Large Area}$$

OKUMURA HATTA MODEL

$$PL = 69.55 + 26,16 \log f_c - 13.82 \log h_b - a(hr) + (44,9 - 6,55 \log (h_m) \log d)$$

Parameter	Notasi	Spesifikasi
Frekuensi Pembawa	Fc	150 -1500 Mhz
Tinggi Antena BTS	Hb	30-200 m
Tinggi Antena MS	Hm	1-10 m
Jarak BTS dengan MS	D	1-20 km

$$a(hr) = (1,1 \log (f) - 0,7)h_b - (1,56 \log (f) - 0,8) \quad ; \text{ Small area}$$
$$a(hr) = 3,2 (\log 11,75h_b)^2 - 1,1 \text{ dB} \quad ; \text{ Large Area}$$

LINK BUDGET

- ▶ COVERAGE PLANNING
- ▶ CAPACITY PLANNING
Based Throughput

COVERAGE PLANNING

Comment Parameter	Unit	Uplink Calculations	Calculation
UE Tx Power	dBm		23 a
Body Loss	dB		2 b
eNB Gain	dB		17 c
Feeder Loss	dB		2 d
TMA nsertion Loss	dBm		0,5 e
Thermal Noise	dB		-203,9772292 f
eNB Noise Figure	dB		4 g
SINR	dB		11 h
			i =
System Bandwidth	dB		69,54242509 $10 \cdot \log(RB \cdot 12 \cdot 15000)$
Receiver Sensitivity	dBm		-119,4348041 j= f+g+h+i
Penetration Loss	dB		10 k
Fading Margin	dB		10 l
Interface Margin	dB		3 m
MAPL	dB		131,9348041 n=a-b+c-d-e+j-k-l-m

Comment Parameter	Unit	Downlink Calculations	Calculation
UE Tx Power	dBm		43 a
Body Loss	dB		3 b
eNB Gain	dB		17 c
Feeder Loss	dB		2 d
TMA insertion Loss	dBm		0,5 e
Thermal Noise	dB		-203,9772292 f
UE Antena Gain	dB		0 g
eNB Noise Figure	dB		6 h
SINR	dB		7 i
			j =
System Bandwidth	dB		69,54242509 $10 \cdot \log(RB \cdot 12 \cdot 15000)$
Receiver Sensitivity	dBm		-121,4348041 k= f+h+i+j
Penetration Loss	dB		10 l
Fading Margin	dB		38 m
Interface Margin	dB		3 n
MAPL	dB		127,9348041 o=a+c-d-e+k-l-m-n

<i>Downlink link budget LTE</i>			
<i>Comment Parameter</i>	<i>Unit</i>	<i>Downlink Calculations</i>	<i>Calculation</i>
<i>Tx RF Power</i>	<i>dBm</i>	43	A
<i>TX Diversity Gain</i>	<i>dB</i>	3	B
<i>Tx RF Line Loss</i>	<i>dB</i>	1	C
<i>Tx Antenna Gain</i>	<i>dB</i>	17	D
<i>Tx AA Gain</i>	<i>dBm</i>	0	E
EIRP	<i>dB</i>	62	f= a+b-c+d+e
<i>Thermal Noise</i>	<i>dBm/Hz</i>	-174	G
<i>Subcarrier Bandwidth</i>	<i>Hz</i>	15000	h
<i>Occupied Subcarriers</i>		600	i= 12*50
<i>Noise Figure</i>	<i>dB</i>	6	J
<i>MCS</i>	<i>dBm</i>	QPSK	K
<i>SNR</i>	<i>dB</i>	1.564	L
<i>Fast Fade Margin</i>	<i>dB</i>	4.5	M
<i>Rx Diversity</i>	<i>dB</i>	3	N
<i>HARQ</i>	<i>dB</i>	0	O
<i>Rx Faded Sensitivity</i>	<i>dBm</i>	-95.3	$p = g + 10\text{LOG} (h*i) + j + l + m - n - o$
<i>Rx Antenna Gain</i>	<i>dB</i>	7	Q
<i>Rx RF Line Loss</i>	<i>dB</i>	0	R
Effective Rx Faded Sensitivity	<i>dBm</i>	-102.3	s = p-q+r
<i>Body, Vehicle, Building Loss</i>	<i>dB</i>	10	T
<i>Interference Margin</i>	<i>dB</i>	2	U
<i>Log Normal margin</i>	<i>dB</i>	6.5	V
MAPL	<i>dB</i>	145.89	w= f -s-t-u-v

<i>Uplink link budget LTE</i>			
<i>Comment Parameter</i>	<i>Unit</i>	<i>Uplink Calculations</i>	<i>Calculation</i>
<i>Tx RF Power</i>	<i>dBm</i>	23	a
<i>TX Diversity Gain</i>	<i>dB</i>	0	b
<i>Tx RF Line Loss</i>	<i>dB</i>	0	c
<i>Tx Antenna Gain</i>	<i>dB</i>	7	d
<i>Tx AA Gain</i>	<i>dBm</i>	0	e
<i>EIRP</i>	<i>dB</i>	30	f= a+b-c+d+e
<i>Thermal Noise</i>	<i>dBm/Hz</i>	-174	g
<i>Subcarrier Bandwidth</i>	<i>Hz</i>	15000	h
<i>Occupied Subcarriers</i>		120	i= 12*10
<i>Noise Figure</i>	<i>dB</i>	4	j
<i>MCS</i>	<i>dBm</i>	QPSK	k
<i>SNR</i>	<i>dB</i>	-4.6	l
<i>Fast Fade Margin</i>	<i>dB</i>	4.5	m
<i>Rx Diversity</i>	<i>dB</i>	3	n
<i>HARQ</i>	<i>dB</i>	0	o
<i>Rx Faded Sensitivity</i>	<i>dBm</i>	-100.5	$p = g + 10\text{LOG} (h*i) + j + l + m - n - o$
<i>Rx Antenna Gain</i>	<i>dB</i>	17	q
<i>Rx RF Line Loss</i>	<i>dB</i>	1	r
<i>Effective Rx Faded Sensitivity</i>	<i>dBm</i>	-126.5	s = p-q+r
<i>Body, Vehicle, Building Loss</i>	<i>dB</i>	10	t
<i>Interference Margin</i>	<i>dB</i>	2	u
<i>Log Normal margin</i>	<i>dB</i>	6.5	v
<i>MAPL</i>	<i>dB</i>	134.0	w= f -s-t-u-v



► $EIRP = P_{tx} + G_{tx_{DG}} - L_{tx} + G_{tx} + G_{tx_{AA}}$

P_{tx} = Daya Transmitter (43 dBm)

$G_{tx_{DG}}$ = Gain diversity transmitter (3 dB)

L_{tx} = Loss Line (1 dB)

G_{tx} = Gain antenna transmitter (17 dB)

$G_{tx_{AA}}$ = Gain adaptive array (0 dBm)

Sehingga didapatkan persamaan seperti berikut :

$$EIRP = 62 \text{ dBm}$$



► $RX_{FS} = kT + 10\text{Log}(SC_{BW} \times SCo) + NF + SNR + FF - G_{RXDG}$

kT = Thermal Noise (-174 dBm)

SC_{BW} = Subcarrier Bandwidth (15kHz)

SCo = Occupied Bandwidth (600)

NF = Noise Figure (6 dB)

SNR = Signal to Noise ratio (1.564 dB)

FF = Fade Margin (4.5 dB)

G_{RXDG} = Rx Diversity Gain (3 dB)

$$RX_{FS} = -174 + 10\text{Log}(15000 \times 600) + 6 + (1.564) + 4.5 - 3 - 0$$

$$RX_{FS} = -95.3 \text{ dBm}$$

► *Thermal Noise = 10 Log (k.T)*

k = konstanta boltzman (1.38×10^{-20}) mWs/K

T = Suhu (290 K)

$$\textit{Thermal Noise} = 10 \log(k.T)$$

$$\textit{Thermal Noise} = 10 \log(1.38 \times 10^{-20} . 290)$$

$$\textit{Thermal Noise} = -174 \text{ dBm/Hz}$$



► *Occupied Subcarrier (SCo)*

$SCo = \text{Resource Block} \times \text{Subcarrier Per Resource Block}$

$SCo = 50 \times 12$

$SCo = 600$

Channel Bandwidth Mhz	1.4	3	5	10	15	20
Subcarrier Bandwidth, Khz	15	15	15	15	15	15
Subcarrier per Resource Block	12	12	12	12	12	12
Number of Resource Block	6	15	25	50	75	100

Tabel Kanal AWGN

MCS index	Downlink			Uplink		
	Modulation	Coding Rate	SNR,dB	Modulation	Coding rate	SNR,dB
0	QPSK	0.1172	-6.475	QPSK	0.1000	-7.231
1	QPSK	0.1533	-5.182	QPSK	0.1250	-6.164
2	QPSK	0.1885	-4.131	QPSK	0.1550	-5.113
3	QPSK	0.2452	-2.774	QPSK	0.2050	-3.701
4	QPSK	0.3008	-1.649	QPSK	0.2500	-2.658
5	QPSK	0.3701	-0.469	QPSK	0.3100	-1.480
6	QPSK	0.4385	0.561	QPSK	0.3650	-0.544
7	QPSK	0.5137	1.564	QPSK	0.4300	0.440
8	QPSK	0.5879	2.479	QPSK	0.4900	1.263
9	QPSK	0.6631	3.335	QPSK	0.5550	2.085
11	16QAM	0.3691	4.140	16QAM	0.3075	2.794
12	16QAM	0.4238	5.243	16QAM	0.3525	3.789
13	16QAM	0.4785	6.285	16QAM	0.4000	4.771
14	16QAM	0.5400	7.403	16QAM	0.4500	5.748
15	16QAM	0.6016	8.478	16QAM	0.5025	6.727
16	16QAM	0.6426	9.168	16QAM	0.5350	7.313
17	64QAM	0.4277	9.168	16QAM	0.5700	7.931
18	64QAM	0.4551	9.846	16QAM	0.6300	8.963
19	64QAM	0.5049	11.060	16QAM	0.6925	10.010
20	64QAM	0.5537	12.250	16QAM	0.7525	10.994
21	64QAM	0.6016	13.398	64QAM	0.5017	10.994
22	64QAM	0.6504	14.534	64QAM	0.5417	11.961
23	64QAM	0.7021	15.738	64QAM	0.5850	12.995
24	64 QAM	0.7539	16.934	64QAM	0.6283	14.017
25	64 QAM	0.8027	18.067	64QAM	0.6700	14.991
26	64QAM	0.8525	19.196	64QAM	0.7100	15.920
27	64QAM	0.8887	20.032	64QAM	0.7417	16.652
28	64QAM	0.9258	20.866	64QAM	0.7717	17.343

► *Effective Rx Faded Sensitivity (RX_{EFS})*

$$RX_{EFS} = RX_{FS} - G_{RX} + L_{RX_LL}$$

$$RX_{FS} = \text{Rx Faded Sensitivity (-102.8 dBm)}$$

$$G_{RX} = \text{Gain Antenna Receiver (7 dB)}$$

$$L_{RX_LL} = \text{RF Line Loss Receiver (0 dB)}$$

$$[RX]_{-}(EFS) = -95,3 - 7 + 0$$

$$[RX]_{-}(EFS) = -102.3 \text{ dBm}$$



► $MAPL = T_{xEIRP} - R_{xEFS} - L_{BV} - M_{interference} - M_{SF}$

T_{xEIRP} = Effective Isotropic Radiated Power (62 dBm)

R_{xEFS} = Effective Rx Faded Sensitivity (-102.3 dBm)

L_{BV} = Body, Vehicle, Building Loss (10 dB)

$M_{interference}$ = Margin Interference (2 dB)

M_{SF} = Log Normal Margin (6.5 dBm)

MAPL = 62 - (-102.3) - 10 - 2 - 6.5

MAPL = 145.89 dBm

► $Lu = 46.3 + 33.9 \log(f) - 13.82 \log(Hb) - a(Hm) + [44.9 - 6.55 \log(Hb)]$

$\log(d) + CM$

$$Lu = 46.3 + 33.9 \log(f) - 13.82 \log(Hb) - a(Hm) + [44.9 - 6.55 \log(Hb)] \log d + C_m$$

$$145.89 = 46.3 + 33.9 \log(1800) - 13.82 \log(40) - 4.37 + [44.9 - 6.55 \log(40)] \log d + 0$$


$$145.89 = 46.3 + 110.35 - 22.14 - 4.37 + 34.41 \log d + 0$$

$$145.89 = 130.14 + 34.41 \log d$$

$$\log[d] = (130.14 - 145.89) / (-34.41)$$

$$\log[d] = 0.45$$

$$d = 2.82 \text{ km}$$



► *Jumlah e Node B = $\frac{\text{Luas Area perencanaan}}{\text{Luas Hexagonal}}$*

Luas Hexagonal = $1.95 \times d^2 \times 2.6$

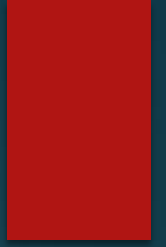
Luas Hexagonal = $1.95 \times 2.82^2 \times 2.6$

Luas Hexagonal = 40,31 km²

Jumlah e Node B = $(63,462) / 40,31$

Jumlah e Node B = 1,54 sites

CAPACITY PLANNING, Based On THROUGHPUT



Network Throughput Based

Traffic Parameters	Uplink				Downlink				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	Throughput/Session (Kbit)	Throughput/Session (Kbit)
VoIP	26.90	80	0.4	1%	26.90	80	0,4	1%	869.49	869.5
Video Phone	62.53	70	1	1%	62.53	70	1	1%	4421.31	4421.31
Video Conference	62.53	1800	1	1%	62.53	1800	1	1%	113690.9	113690.9
Real Time Gaming	31.26	1800	0.2	1%	125.06	1800	0,4	1%	11367.3	90952.7
Streaming Media	31.26	3600	0.05	1%	250.11	1800	0,05	1%	5683.6	864016.4
IMS Signalling	15.63	7	0.2	1%	15.63	7	0,2	1%	22.1	22.1
Web Browsing	62.53	1800	0.05	1%	250.11	1800	0,05	1%	5684.5	22737.3
File Transfer	140.69	600	1	1%	750.34	600	1	1%	85266.6	454751.5
Email	140.69	50	1	1%	750.34	15	1	1%	7105.6	11368.8
P2P File Sharing	250.11	1200	1	1%	750.34	1200	1	1%	303163.6	909575.8

Traffic Model For Various Environment

User Behaviour	Dense Urban		Urban		Suburban		Rural	
	Penetration Ratio	BHSA	Penetration Ratio	BHSA	Penetration Ratio	BHSA	Penetration Ratio	BHSA
VoIP	100%	1.4	100%	1.3	50%	1	50%	0.9
Video Phone	20%	0.2	20%	0.16	10%	0.1	5%	0.05
Video Conference	20%	0.2	15%	0.15	10%	0.1	5%	0.05
Real Time Gaming	30%	0.2	20%	0.2	10%	0.1	5%	0.1
Streaming Media	15%	0.2	15%	0.15	5%	0.1	5%	0.1
Signalling	40%	5	30%	4	25%	3	20%	3
Web Browsing	100%	0.6	100%	0.4	40%	0.3	30%	0.2
File Transfer	20%	0.3	20%	0.2	20%	0.2	10%	0.2
Email	10%	0.4	10%	0.3	10%	0.2	5%	0.1
P2P File Sharing	20%	0.2	20%	0.3	20%	0.2	5%	0.1

Throughput

$$Thr_{session} = R_{bearer} \times t_{session} \times D \times (1/(1 - BLER))$$

$Thr_{session}$ = Banyaknya bit yang diterima oleh tiap *user equipment* (UE) per-sesi suatu layanan

R_{bearer} = Laju data pada *layer* aplikasi (*bearer rate*)

$t_{session}$ = *Session time*, durasi suatu layanan

D = *Duty Ratio*, laju transmisi data per-sesi suatu layanan

$BLER$ = *Block Error Rate*, laju error layanan karena kapasitas penuh/*blocking*

Single User Throughput

$$Thr_{SU} = \frac{Thr_{session} \times BHSA \times R_{penetration} \times R_{PAV}}{3600 s}$$

Thr_{SU} = Rata-rata banyaknya bit yang diterima oleh tiap UE per-layanan

$Thr_{session}$ = Banyaknya bit yang diterima oleh tiap UE per-sesi suatu layanan

$BHSA$ = *Busy Hour Service Attempt*, percobaan untuk mendapatkan suatu layanan oleh UE pada jam sibuk

$R_{penetration}$ = *Penetration Ratio*, yaitu seberapa bagus suatu layanan dapat mempengaruhi *subscriber*

R_{PAV} = *Peak To Average Ratio*, Asumsi prosentase beban lebih jaringan terbesar yang bisa terjadi pada area tertentu (di modul ini hanya menggunakan area urban dan suburban)

Network Throughput

UL Network Throughput (IP) = Total User Number x UL Single User Throughput

DL Network Throughput (IP) = Total User Number x DL Single User Throughput

- ❑ Total user number = Forecasting number of users in an operator
- ❑ UL Single user throughput = Total uplink throughput of a single user in desired service area
- ❑ DL Single user throughput = Total downlink throughput of a single user in desired service area

Up and Down Cell capacity

$$\text{DL Cell Capacity} + \text{CRC} = (168 - 36 - 12) \times (\text{Code bits}) \times (\text{Code Rate}) \times N_{\text{rb}} \times C \times 1000$$

$$\text{UL Cell Capacity} + \text{CRC} = (168 - 24) \times (\text{Code bits}) \times (\text{Code Rate}) \times N_{\text{rb}} \times C \times 1000$$

Amount Of eNodeB

$$\text{Number of Site} = \frac{\text{Network Throughput}}{\text{Site Capacity}}$$