

# CS-224 (Computer Networks)

## Homework-1

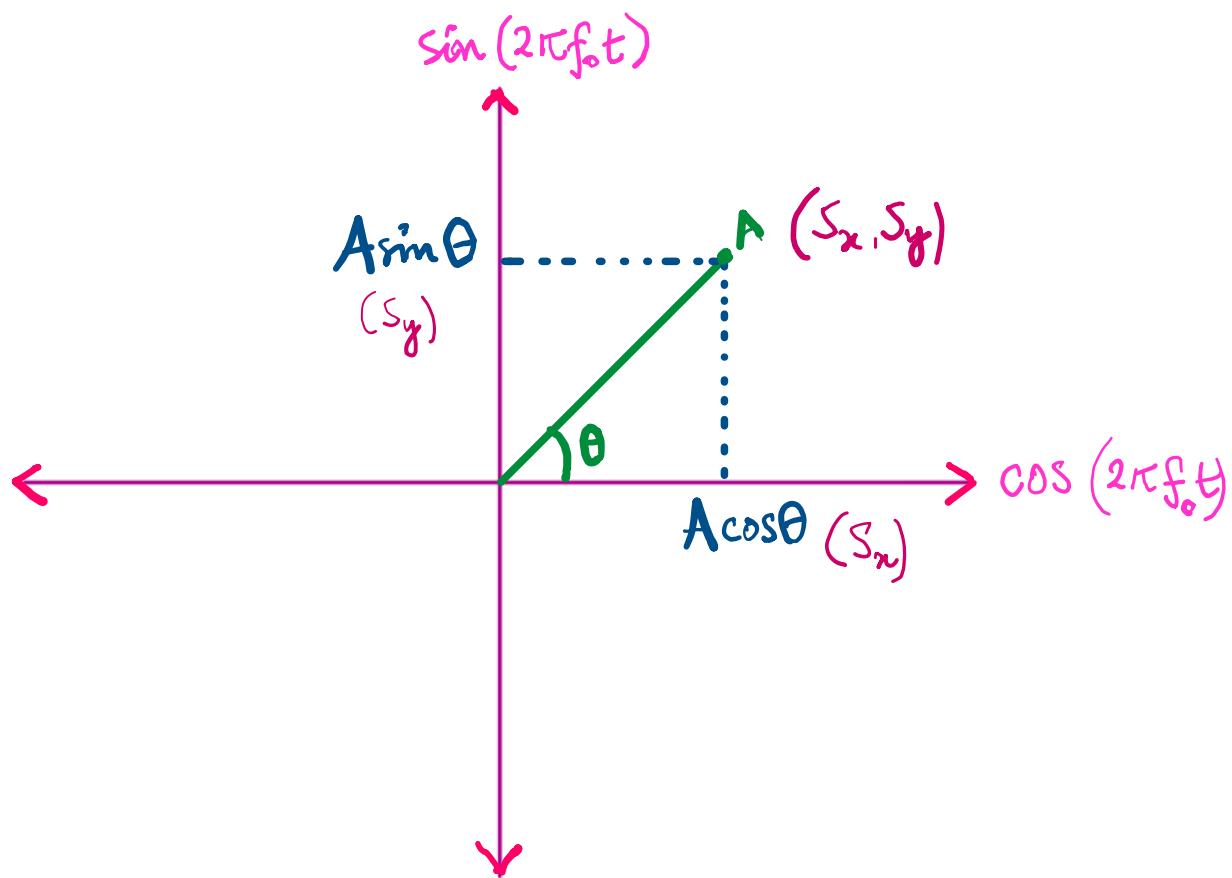
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**Roll No:** 22B3936

**Instructor:** Prof. Vinay Ribeiro

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### Constellation Diagram



\* Transmitted signal is  $s(t) = (s_x, s_y)$ .

\* Unit vector along x-axis:  $\sqrt{\frac{2}{T}} \cos(2\pi f_0 t)$

\* Unit vector along y-axis:  $\sqrt{\frac{2}{T}} \sin(2\pi f_0 t)$

\*  $\langle g(t), h(t) \rangle = \int_0^T g(t)h(t) dt$

$$* \|s\|^2 := \langle s(t), s(t) \rangle = s_x^2 + s_y^2 \quad (\text{Transmitted energy})$$

\*  $\alpha \rightarrow$  attenuation factor

\* Received constellation point  $\underline{r} = (r_x, r_y)$

where  $r_x = \alpha s_x + n_x$ ,  $r_y = \alpha s_y + n_y$

\*  $N_0 \rightarrow$  noise energy per symbol

$$* \text{SNR per symbol} = \frac{\alpha^2 \times \text{Avg energy per transmitted symbol}}{\text{noise energy per symbol}}$$

$$* Q(z) = \frac{1}{\sqrt{2\pi}} \int_z^\infty e^{-(x^2/2)} dx$$

1] In the given QM, if  $(A, 0)$  is transmitted then the distribution of  $r_x$  is  $\mathcal{N}(\alpha A, \frac{N_0}{2})$

$\alpha A$  → mean  
 $\frac{N_0}{2}$  → variance

(BPSK)

Incorrect detections:

Case 1 → Sent 0 but received 1 →  $P = P_1$   
 Case 2 → Sent 1 but received 0 →  $D = D_1$

Case 1  $\rightarrow$  Sent 0 but received 1  $\rightarrow P = P_1$   
 Case 2  $\rightarrow$  Sent 1 but received 0  $\rightarrow P = P_2$

By symmetry of system,  $P_1 = P_2$

$$\therefore P_{\text{total}} = \frac{1}{2} \times P_1 + \frac{1}{2} \times P_2 = \underbrace{\left( \frac{1}{2} + \frac{1}{2} \right)}_{(\because 0, 1 \text{ are equiprobable})} P_1 = P_1$$

Probability of bit error:  $P(Y_n < 0) = \frac{1}{\sigma \sqrt{2\pi}} \int_{-\infty}^0 e^{-\frac{1}{2} \left( \frac{x - \alpha A}{\sigma} \right)^2} dx$

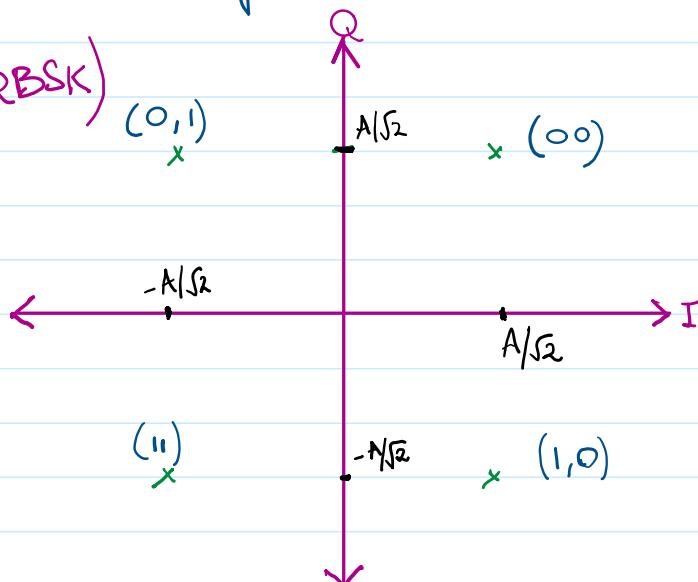
Substituting  $y = \frac{x - \alpha A}{\sigma} \Rightarrow dy = \frac{dx}{\sigma}$

$$\therefore \frac{1}{\sigma \sqrt{2\pi}} \int_{-\infty}^{-\frac{\alpha A}{\sigma}} e^{-\frac{1}{2} y^2} dy$$

$$= Q\left(\sqrt{\frac{\alpha^2 A^2}{N_0/2}}\right) = \boxed{Q(\sqrt{2 \cdot \text{SNR}})}$$

$\therefore$  Gaussian fn is symmetric,  
 we get same answer for  $(-A, 0)$ .

2] (QPSK)

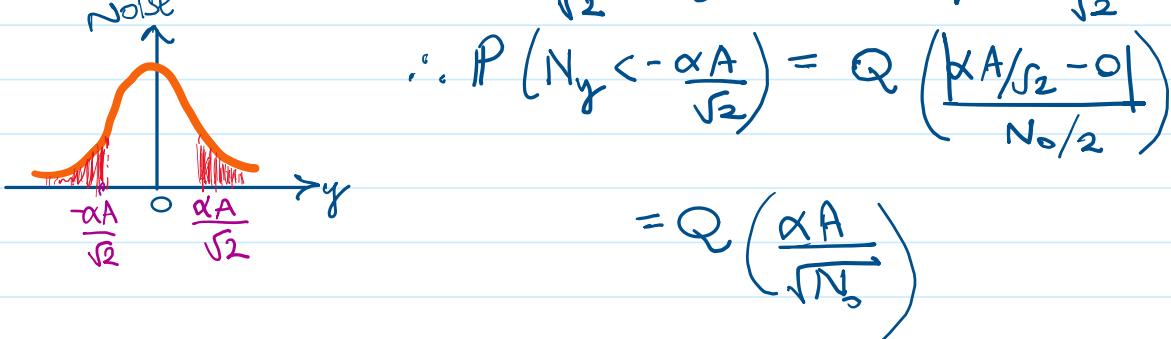


$r_x$	$r_y$	$B_1$	$B_2$	$\theta_s$
$>0$	$>0$	0	0	$\pi/4$
$<0$	$>0$	0	1	$3\pi/4$
$<0$	$<0$	1	1	$5\pi/4$
$>0$	$<0$	1	0	$7\pi/4$

Considering case 1: Bit transmitted = 0  
 Bit received = 1

$$S_y = \frac{A}{\sqrt{2}}, \quad V_y = \frac{-A}{\sqrt{2}}$$

$$\alpha S_y + N_y < 0 \Rightarrow \frac{\alpha A}{\sqrt{2}} + N_y < 0 \Rightarrow N_y < -\frac{\alpha A}{\sqrt{2}}$$



$$P(\text{error in Bit 1}) = \frac{1}{2} P(\text{case 1}) + \frac{1}{2} P(\text{case 2})$$

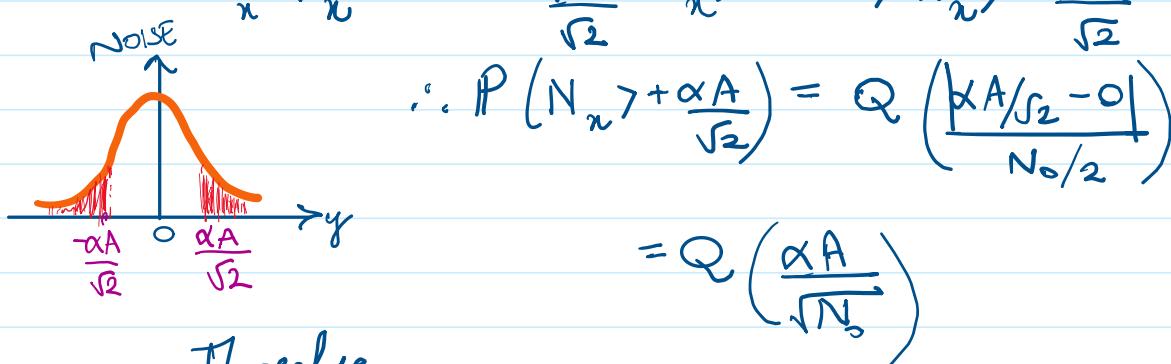
$$= \frac{1}{2} \times 2 Q\left(\frac{\alpha A}{\sqrt{N_0}}\right) = Q\left(\frac{\alpha A}{\sqrt{N_0}}\right)$$

$$= Q(\sqrt{\text{SNR}})$$

Considering case 2: Bit transmitted = 1  
Bit received = 0

$$S_n = -\frac{A}{\sqrt{2}}, \quad V_n = \frac{A}{\sqrt{2}}$$

$$\alpha S_n + N_n > 0 \Rightarrow -\frac{\alpha A}{\sqrt{2}} + N_n > 0 \Rightarrow N_n > +\frac{\alpha A}{\sqrt{2}}$$



Therefore,

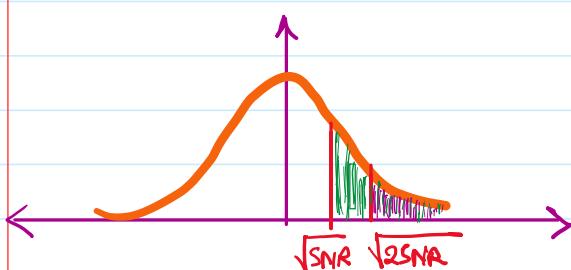
$$P(\text{error in Bit 2}) = \frac{1}{2} P(\text{case 1}) + \frac{1}{2} P(\text{case 2})$$

$$= \frac{1}{2} \times 2 Q\left(\frac{\alpha A}{\sqrt{N_0}}\right) = Q\left(\frac{\alpha A}{\sqrt{N_0}}\right)$$

=  $Q(\sqrt{\text{SNR}})$

∴  $\text{BER} =$

$$= Q(\sqrt{\text{SNR}})$$



Clearly,

$$Q(\sqrt{\text{SNR}}) > Q(\sqrt{2\text{SNR}})$$

(Area under Gaussian)

∴

### CONCLUSION:

The probability of a bit being in error is greater in QPSK as compared to BPSK.

## Lab

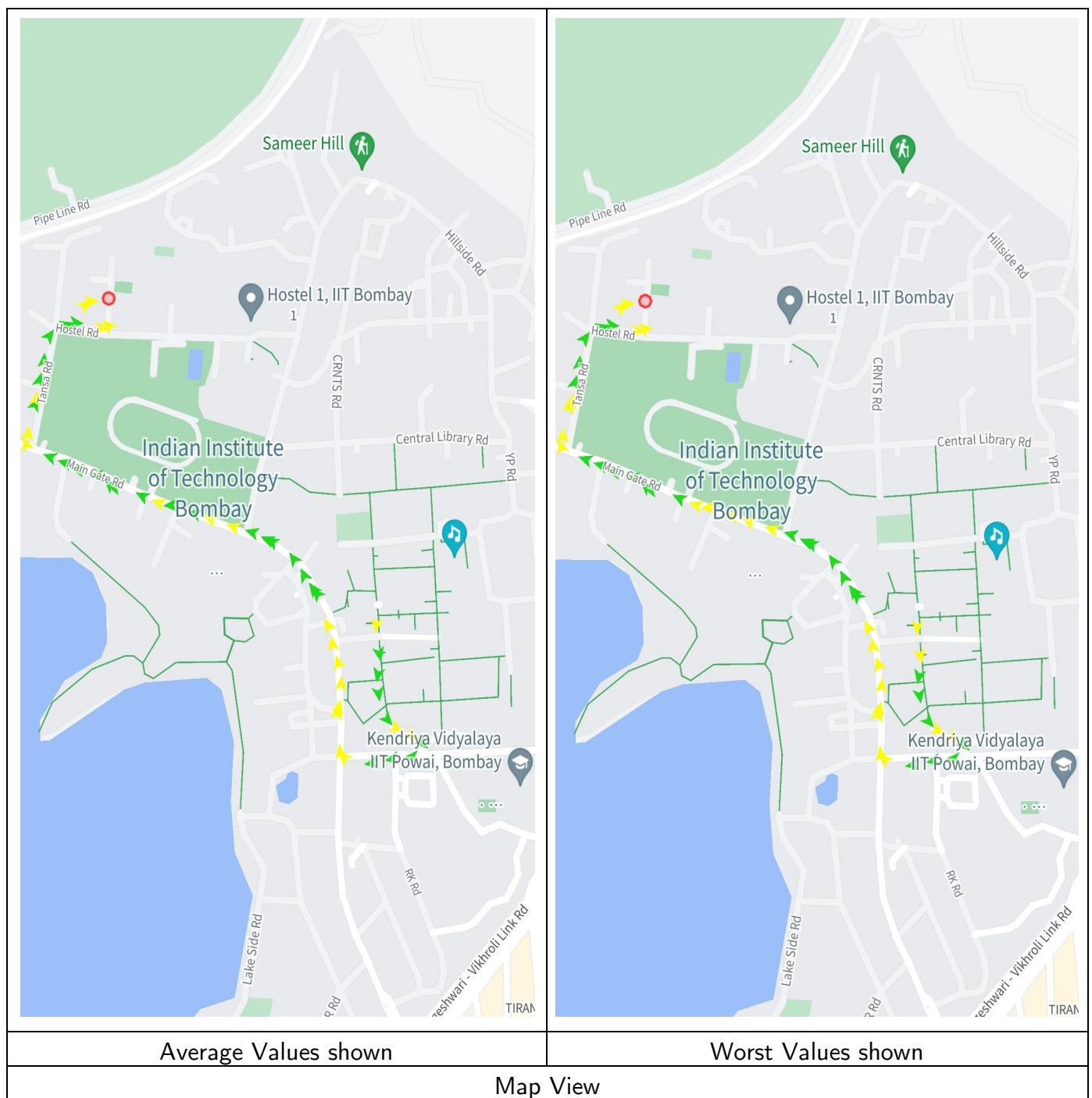
The screenshots of signal strength are provided below in both map and satellite view. The data is generated using the Android App “NetMonitor Cell Signal Logging Lite” by walking around IITB Campus.

A signal is considered

- **good** – if the signal strength is greater than -85dBm
- **not bad** – if the signal strength is greater than -105dBm and less than or equal to -85dBm
- **bad** – if the signal strength is less than or equal to -105dBm

### Observations

- There has been 4G signal throughout the path.
- The signal is consistently good near the Main Building, and average between the hostels.





Average Values shown

Worst Values shown

Satellite View

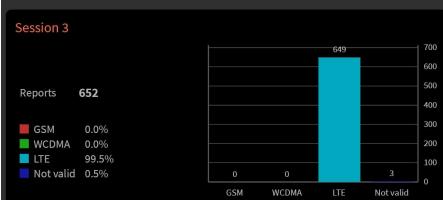


## From Electrical building to Convocation hall

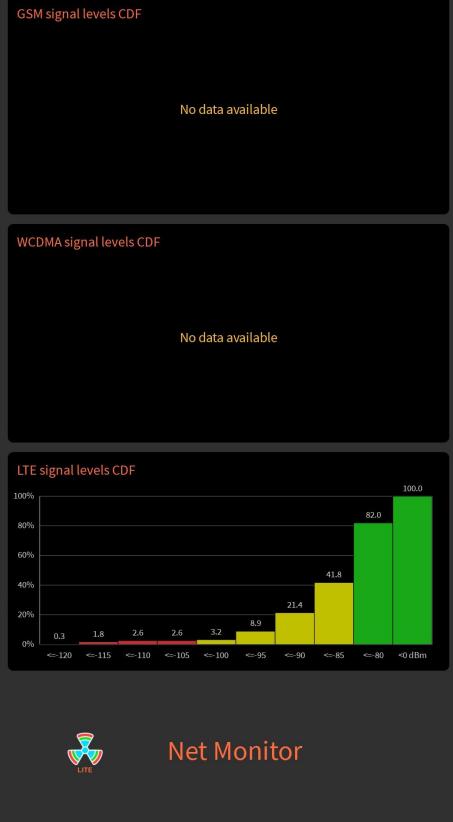
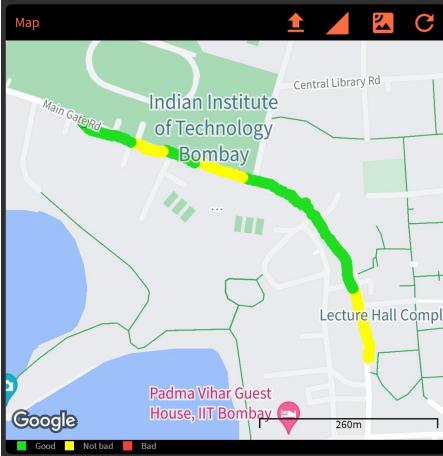


## From Lecture hall complex to IITB Hospital

Session: Session 3  
SIM Operator: airtel  
Fragment: 2023.08.31 19:21:41-19:23:41

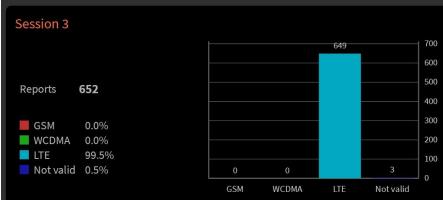


L1800 RSRP: -81 dBm RSRQ: -15 dB RSSNR: -- dB (last point)  
TAC: 6035 eNodebid: 906129 Cl: 2 PCI: 64 ARFCN: 1484  
Distance: -- m. Cell: --

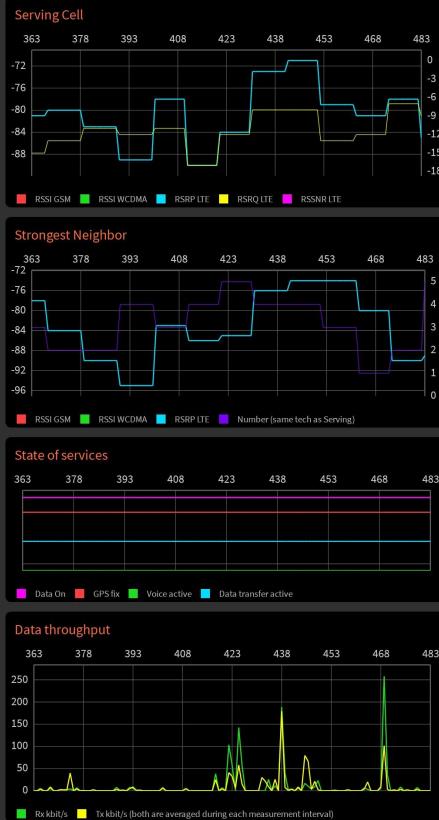
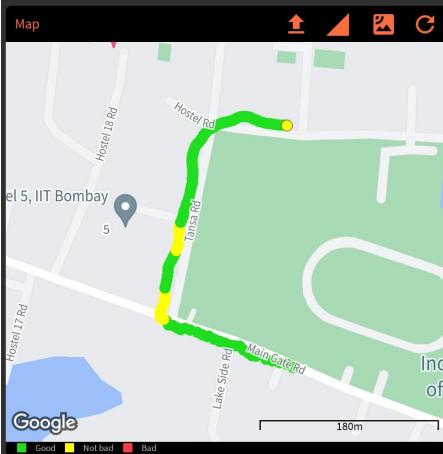


## From Convocation Hall to New SAC

Session: Session 3  
SIM Operator: airtel  
Fragment: 2023.08.31 19:23:42-19:25:42



L1800 RSRP: -85 dBm RSRQ: -9 dB RSSNR: -- dB (last point)  
TAC: 6035 eNodebid: 900353 Cl: 3 PCI: 7 ARFCN: 1484  
Distance: -- m. Cell: --

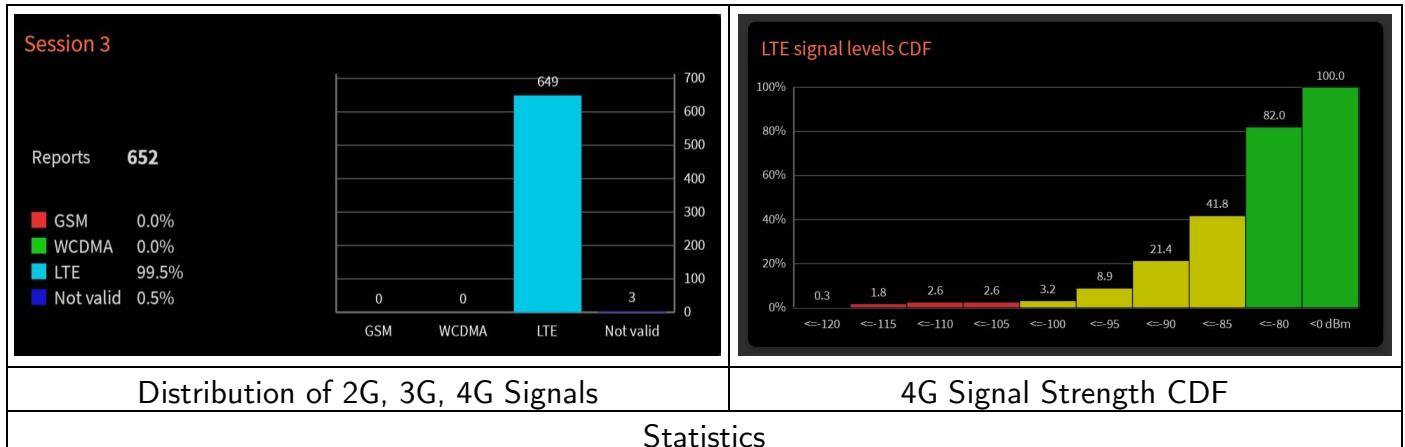


## From Hostel-11 to Hostel-3



## In and Around H-3

### Statistics



### Statistics

Note: The possible causes of variation in the signal strength could be the obstructions due to the buildings and other tall structures.