mComm – Communication Backbone of Indian Railways Cab-Signalling based ATP

24.08.2023

Lalit K Mansukhani, IRSSE +91 9701518800
OSD/Centre of Excellence/IRISET

1

Multi-source Interoperability based on open protocols to avoid monopoly

2

Options of Info Transfer Mechanisms for ATP Development

- **Development of MComm as substitute of GSM-R, LTE to act as Communication Backbone of ATP system, triggered the development of radio-based Cab-signalling IR-ATP Kavach.**

Spot Transmission:

- Adverse to Line Capacity
- Simple Design
- One-way Info flow at certain spots
- Cables, Trackside Electronics
- Hindrance to Track/ P.Way

Radio-based Transfer:

- Line Capacity Friendliness
- Line Capacity Enhancement
- Multi-way Info flow
- Needs Radio Communication
- GSM-R obsolescence
- LTE wasn't available, wait

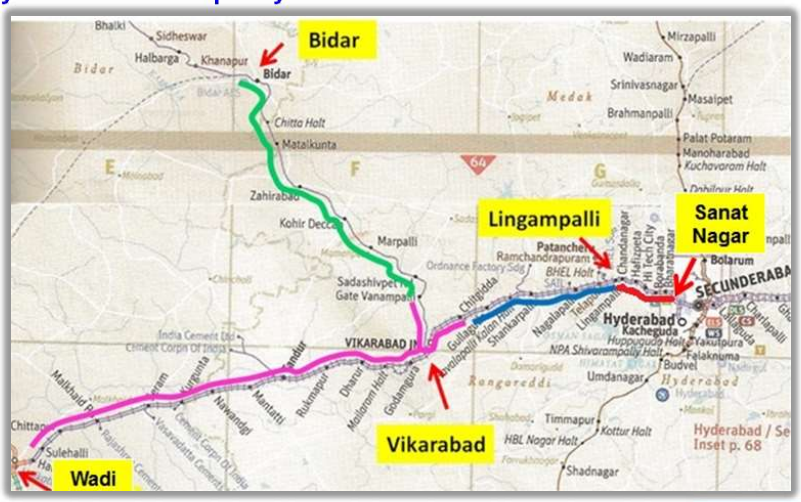
3

Demo of Line Capacity Enhancement in Auto Signalling Section

- In 2015, the Auto Signalling Section Sanatnagar – Hafizpeta - Lingampalli was added to original 250km section to demonstrate advantages of radio-based system for Line Capacity Enhancement.

Colour Legend:

- Medha
- Kernex
- HBL
- All 03 in Auto Sig Section



4

Avoiding clashes in payload transmission by various entities

Communication clashes would be avoided if at least one of following is different:

- **Time**
- **Frequency**
- **Location (far apart)**

Payload by Stationary Units

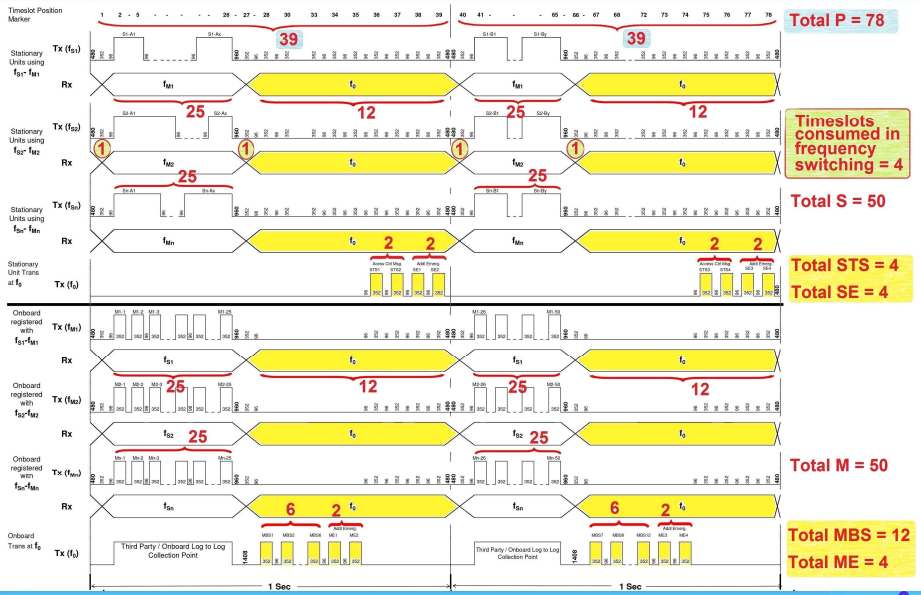
- **Different Timings : TDM (Fixed)**
- **Different Frequencies : FDM (Fixed)**
- **Reuse over Space Domain**

Payload by Onboard Units

- **Different Timings : TDMA (Dynamic)**
- **Different Frequencies : FDMA (Dynamic)**
- **Reuse over Space Domain**

5

Complete Kavach (TCAS) MCOMM Frame Structure
Total 02 Sec @19.2 kbps Over-The-Air i.e Total 38,400 bits



6

Considerations for Kavach Radio Comm (MCOMM)

- Open radio protocols to achieve multi-vendor interoperability.
- Stringent requirements for radio security due to open protocols.
- Information loss due to clash of comm. if two units in geographic vicinity transmit at same time instant and at same frequency.
- One third of time frame is dedicated to Control, Command, Access, Repeat Emergency, Direct Onboard-to-Onboard messages at predecided universally known frequency and time instants.
- Two third of time frame is dedicated for payload info exchange.
- Stationary and Onboard Units transmit at Separate frequency channels.
- Stationary units transmit payload info at different time instants (TDM) and different frequencies (FDM).
- Mobile Onboard Units transmit payload info at different time instants (TDMA) and different frequencies (FDMA)
- Reuse time and frequency over Space Domain beyond overreach

7

Frame Structure

- 2 sec (2000 m-sec) timeframe is divided in 02 identical halves.
- Over-The-Air@19.2.kbps, Total number of bits in frame:38,400
- The frame is divided into total 78 timeslot position markers each of 352 bits. Guard time 96 bits (5 m-sec).
- Freq transition and stabilization time : 1408 bits (73.33 m-sec).
- Full Duplex Hardware but Operation is not full-duplex.
- 50 timeslot positions for payload (TDM/TDMA/FDM/FDMA).
- 24 timeslots (Yellow shaded) for onboard-to-onboard, Emergency Additional message, Access, Command.
- Each Onboard trans : fixed duration of one marker i.e 352 bits
- Each Stationary is using contiguous wider timeslot consisting of more than one position markers.
- Total {(352x39 + 96x37 + 480x2 +960) x2} = 38,400 bits
- Time frame in all units is synchronized through GPS/GNSS.
- Data packet of length more than 1024 bits is fragmented.

8

Distribution of 78 Timeslot Position Markers

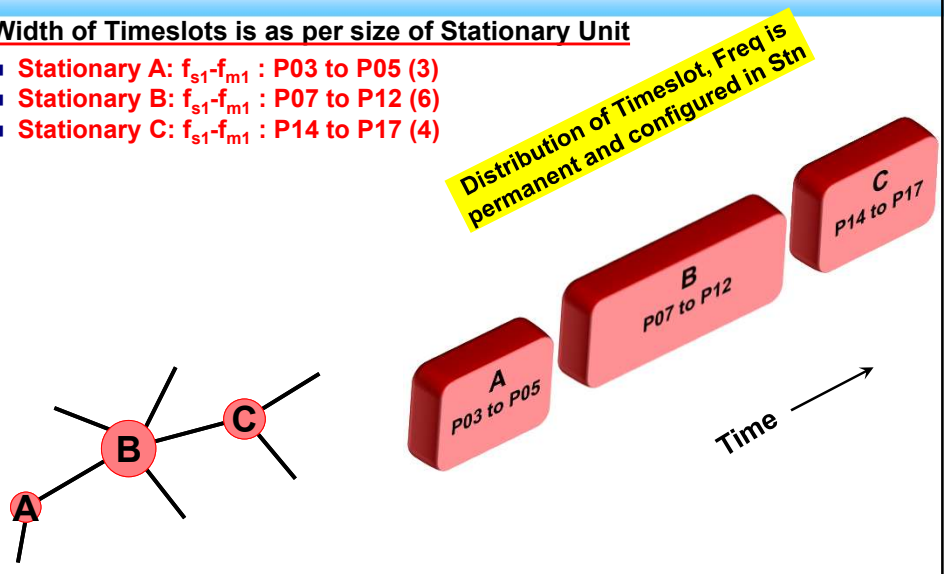
- P1, P27, P40, P66 : Total 4
  Not used for Trans, Sacrificed for Freq Switching, Stabilization
- P2 to P26 (M1 to M25), P41 to P65 (M26 to M50) : Total 50
  Payload from Stationary to Onboard, Onboard to Stationary
- P28 to P33, P67 to P72 : Total 12 (on f_0)
  Broadcast by Onboard Units in Block Section
- P34, P35, P73, P74 : ME-1 to ME-4 : Total 4 (on f_0)
  Broadcast of additional emergency (SoS) msg by Onboard.
- P36, P37, P75, P76 : STS-1 to STS-4 : Total 4 (on f_0)
  Broadcast of Access Authority Packets by Stationary
- P38, P39, P77, P78 : SE-1 to SE-4 : Total 4 (on f_0)
  Broadcast of additional emergency (SoS) msg by Stationary

9

Stationary Units: Distribution of Timeslots and Freq Channels

Width of Timeslots is as per size of Stationary Unit

- Stationary A: f_{s1}-f_{m1} : P03 to P05 (3)
- Stationary B: f_{s1}-f_{m1} : P07 to P12 (6)
- Stationary C: f_{s1}-f_{m1} : P14 to P17 (4)

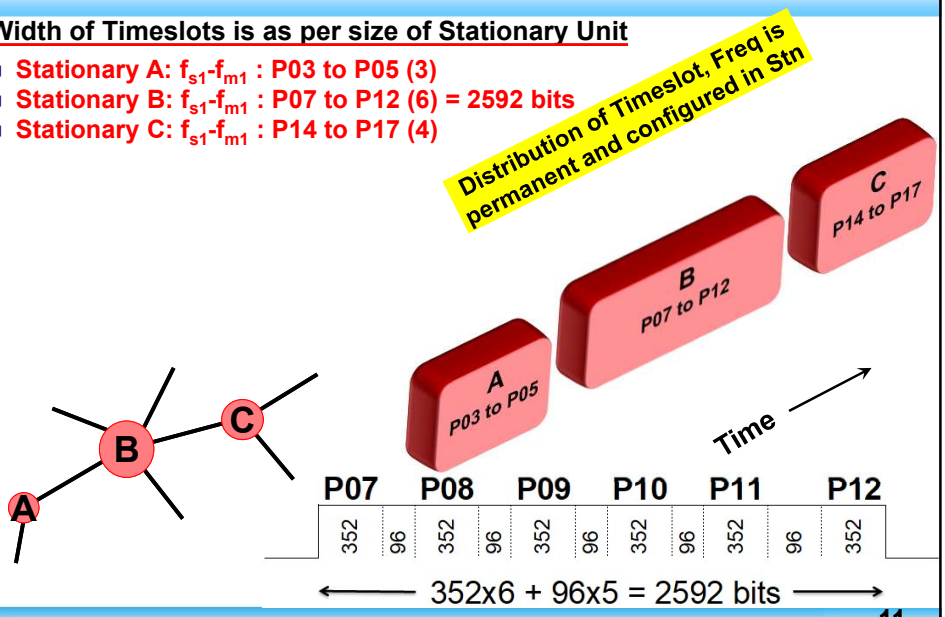


10

Stationary Units: Distribution of Timeslots and Freq Channels

Width of Timeslots is as per size of Stationary Unit

- Stationary A: f_{s1}-f_{m1} : P03 to P05 (3)
- Stationary B: f_{s1}-f_{m1} : P07 to P12 (6) = 2592 bits
- Stationary C: f_{s1}-f_{m1} : P14 to P17 (4)

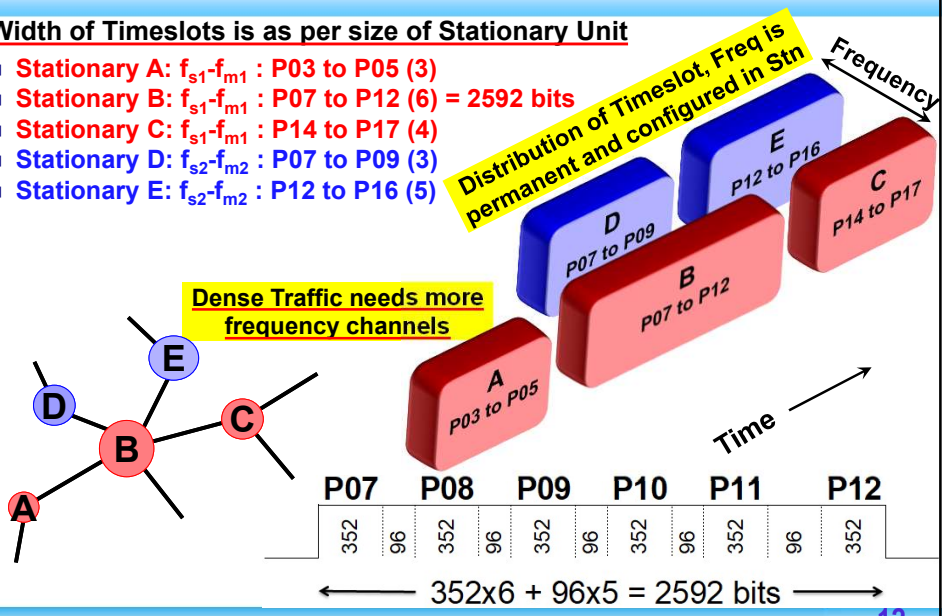


11

Stationary Units: Distribution of Timeslots and Freq Channels

Width of Timeslots is as per size of Stationary Unit

- Stationary A: f_{s1}-f_{m1} : P03 to P05 (3)
- Stationary B: f_{s1}-f_{m1} : P07 to P12 (6) = 2592 bits
- Stationary C: f_{s1}-f_{m1} : P14 to P17 (4)
- Stationary D: f_{s2}-f_{m2} : P07 to P09 (3)
- Stationary E: f_{s2}-f_{m2} : P12 to P16 (5)

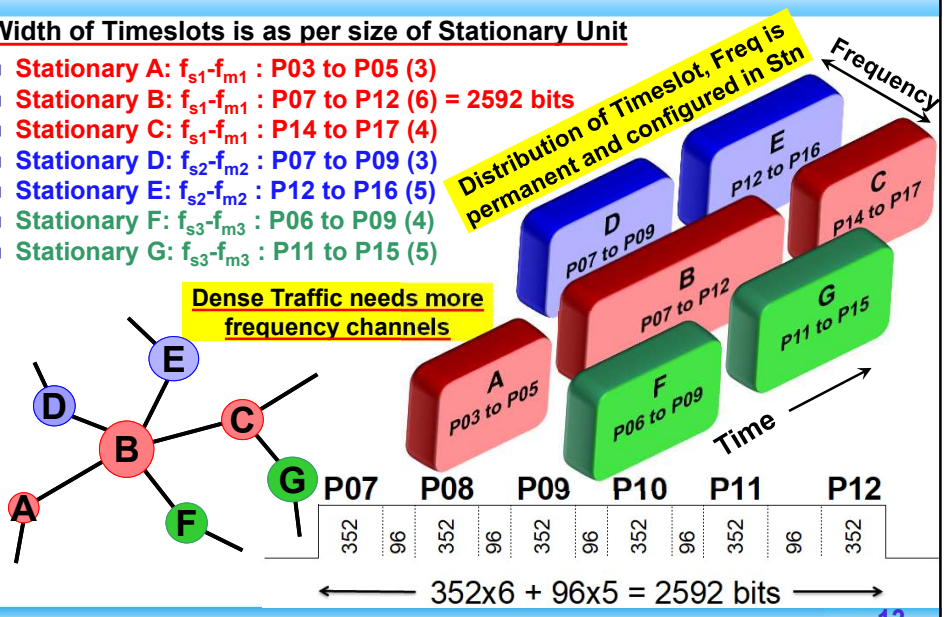


12

Stationary Units: Distribution of Timeslots and Freq Channels

Width of Timeslots is as per size of Stationary Unit

- Stationary A: f_{s1}-f_{m1} : P03 to P05 (3)
- Stationary B: f_{s1}-f_{m1} : P07 to P12 (6) = 2592 bits
- Stationary C: f_{s1}-f_{m1} : P14 to P17 (4)
- Stationary D: f_{s2}-f_{m2} : P07 to P09 (3)
- Stationary E: f_{s2}-f_{m2} : P12 to P16 (5)
- Stationary F: f_{s3}-f_{m3} : P06 to P09 (4)
- Stationary G: f_{s3}-f_{m3} : P11 to P15 (5)

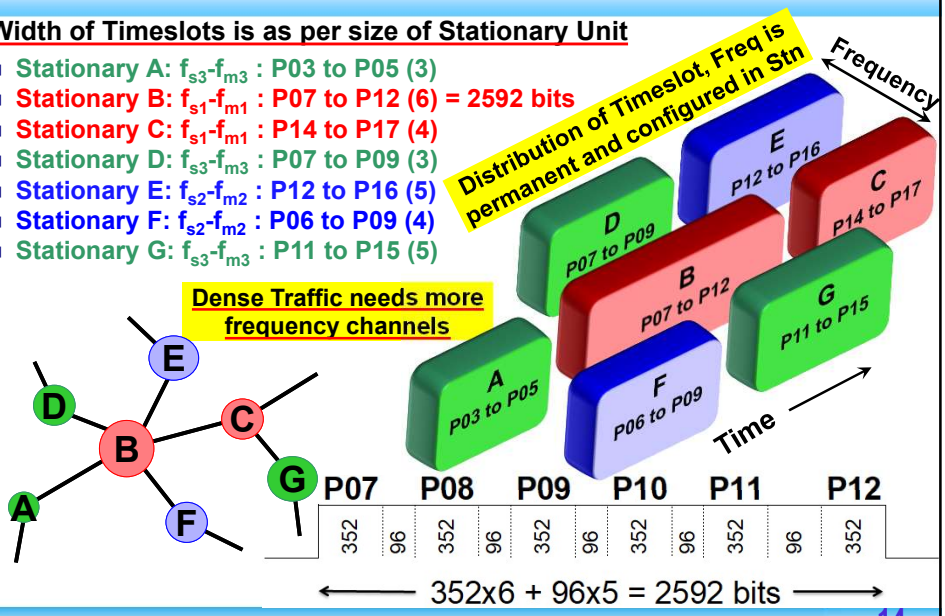


13

Stationary Units: Distribution of Timeslots and Freq Channels

Width of Timeslots is as per size of Stationary Unit

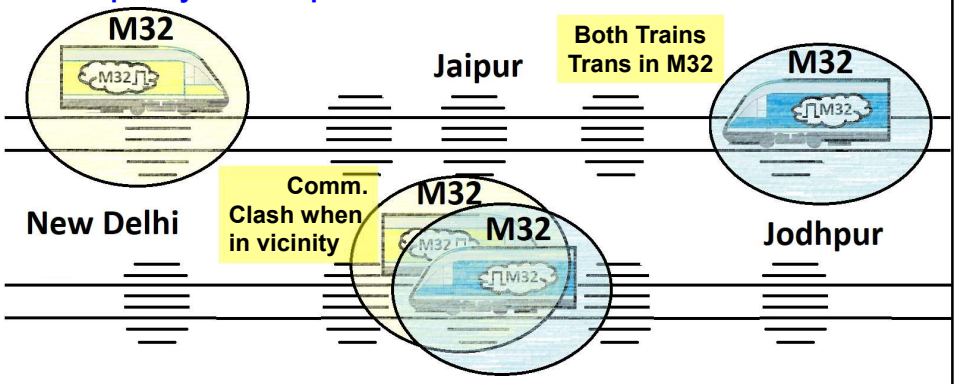
- Stationary A: f_{s3}-f_{m3} : P03 to P05 (3)
- Stationary B: f_{s1}-f_{m1} : P07 to P12 (6) = 2592 bits
- Stationary C: f_{s1}-f_{m1} : P14 to P17 (4)
- Stationary D: f_{s3}-f_{m3} : P07 to P09 (3)
- Stationary E: f_{s2}-f_{m2} : P12 to P16 (5)
- Stationary F: f_{s2}-f_{m2} : P06 to P09 (4)
- Stationary G: f_{s3}-f_{m3} : P11 to P15 (5)



14

Onboard Units: Can we afford dedicated permanent timeslot ?

- Width of train transmit timeslot is fixed irrespective of type of train.
- 'N' frequency channel pairs can handle '50N' train timeslots.

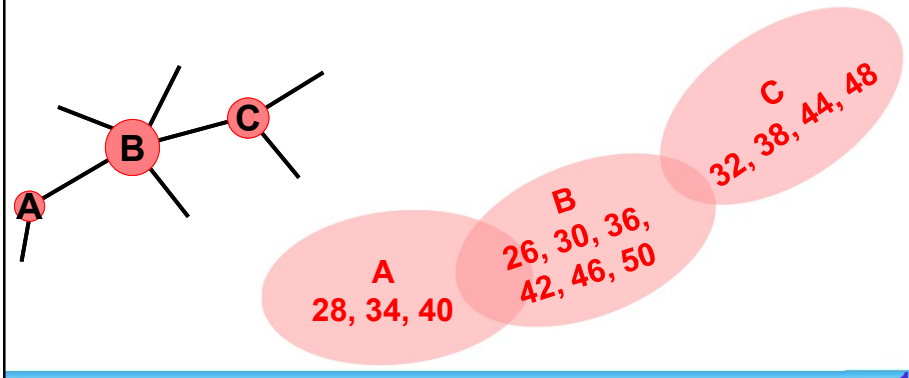


- 10,000 trains with dedicated timeslots require 200 frequency channel pairs. Requires very large spectrum, wider band antennae, reduced performance.
- With dedicated timeslots permanently assigned to trains, only 250 trains can be catered even with 05 frequency channel pairs.

15

Freq and Timeslots of Onboard Trans assigned by Stationary

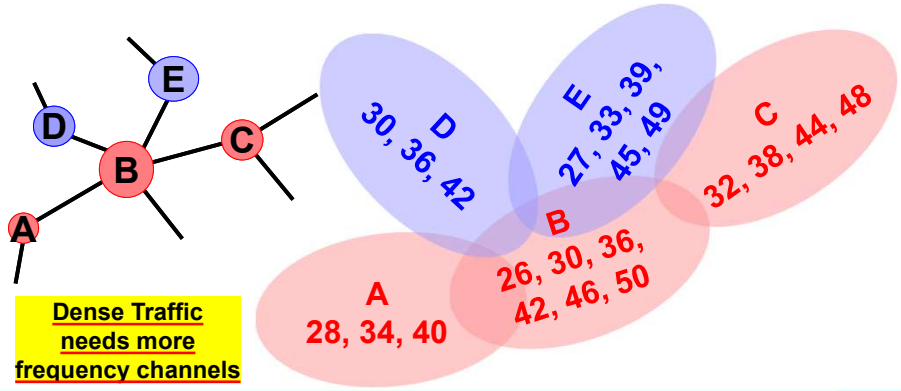
- Stationary A: f_{s1}-f_{m1} : Can handle 03 trains : M28, M34, M40
- Stationary B: f_{s1}-f_{m1} : Can handle 06 trains : M26, M30, M36, M42, M46, M50
- Stationary C: f_{s1}-f_{m1} : Can handle 04 trains : M32, M38, M44, M48



16

Freq and Timeslots of Onboard Trans assigned by Stationary

- Stationary A: f_{s1}-f_{m1} : Can handle 03 trains : M28, M34, M40
- Stationary B: f_{s1}-f_{m1} : Can handle 06 trains : M26, M30, M36, M42, M46, M50
- Stationary C: f_{s1}-f_{m1} : Can handle 04 trains : M32, M38, M44, M48
- Stationary D: f_{s2}-f_{m2} : Can handle 03 trains : M30, M36, M42
- Stationary E: f_{s2}-f_{m2} : Can handle 05 trains : M27, M33, M39, M45, M49

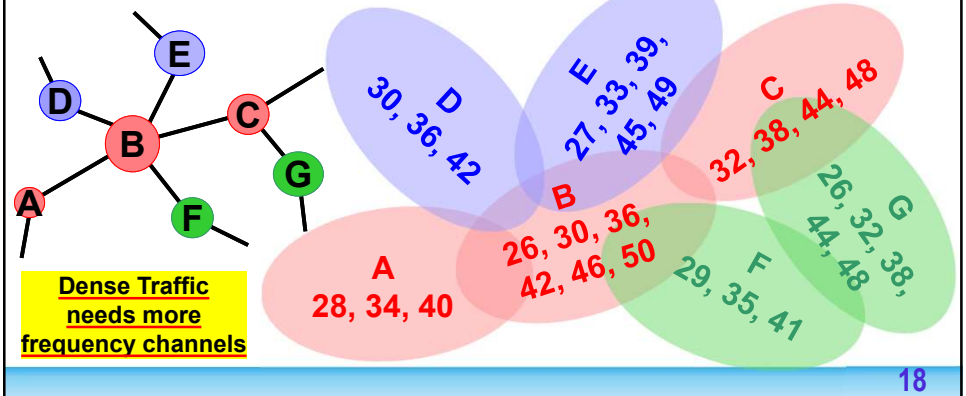


Dense Traffic needs more frequency channels

17

Freq and Timeslots of Onboard Trans assigned by Stationary

- Stationary A: f_{s1}-f_{m1} : Can handle 03 trains : M28, M34, M40
- Stationary B: f_{s1}-f_{m1} : Can handle 06 trains : M26, M30, M36, M42, M46, M50
- Stationary C: f_{s1}-f_{m1} : Can handle 04 trains : M32, M38, M44, M48
- Stationary D: f_{s2}-f_{m2} : Can handle 03 trains : M30, M36, M42
- Stationary E: f_{s2}-f_{m2} : Can handle 05 trains : M27, M33, M39, M45, M49
- Stationary F: f_{s3}-f_{m3} : Can handle 03 trains : M29, M35, M41
- Stationary G: f_{s3}-f_{m3} : Can handle 05 trains : M26, M32, M38, M44, M48

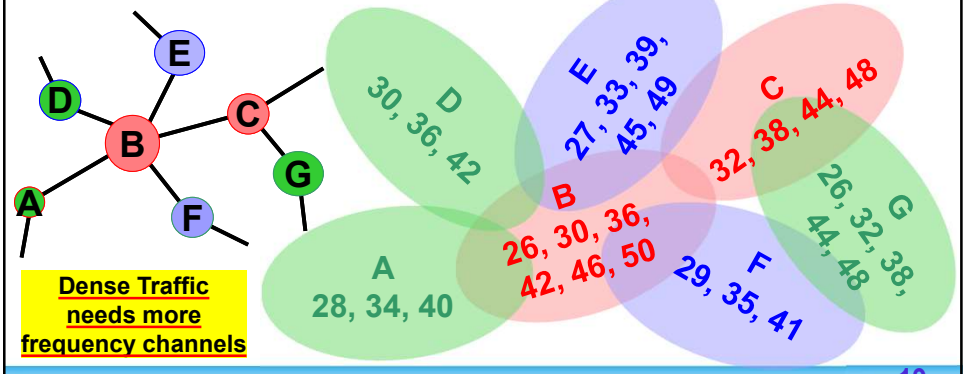


Dense Traffic needs more frequency channels

18

Freq and Timeslots of Onboard Trans assigned by Stationary

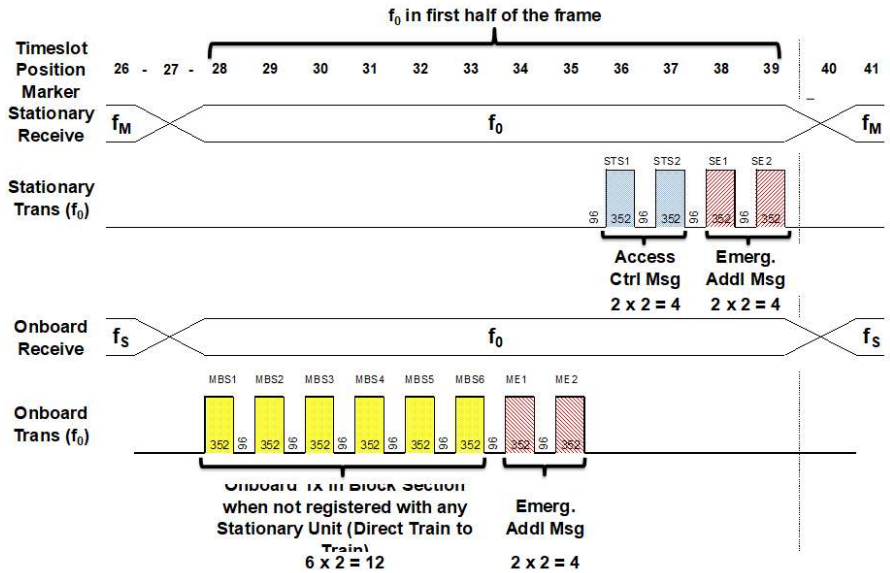
- Stationary A: f_{s1}-f_{m1} : Can handle 03 trains : M28, M34, M40
- Stationary B: f_{s1}-f_{m1} : Can handle 06 trains : M26, M30, M36, M42, M46, M50
- Stationary C: f_{s1}-f_{m1} : Can handle 04 trains : M32, M38, M44, M48
- Stationary D: f_{s2}-f_{m2} : Can handle 03 trains : M30, M36, M42
- Stationary E: f_{s2}-f_{m2} : Can handle 05 trains : M27, M33, M39, M45, M49
- Stationary F: f_{s3}-f_{m3} : Can handle 03 trains : M29, M35, M41
- Stationary G: f_{s3}-f_{m3} : Can handle 05 trains : M26, M32, M38, M44, M48



Dense Traffic needs more frequency channels

19

Control, Command, Direct Onboard-to-Onboard : Frequency Inversion



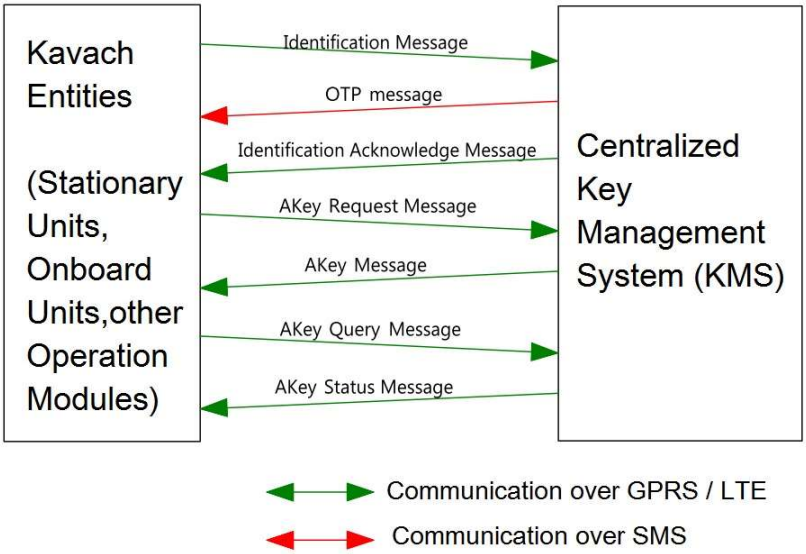
20

Radio Security : Solution to Open Protocols challenges

- Multi-vendor interoperability requires open radio communication protocols.
- Security requirements are more stringent for open radio protocols.
- AES-128 encryption is used.
- Each communication session should have unique encryption.
  - Different Onboard at same Trackside unit : different encryption.
  - Same Onboard at different Trackside unit: different encryption.
  - Same Onboard at same Trackside but at different time: different encryption.
- Only legitimate units should be allowed to participate
- Above is achieved by deriving a Session Key K_s which is based on:
  - A random number R_1 generated by Onboard Unit afresh for every session
  - A random number R_2 generated by Trackside Unit afresh for every session
  - Authentication Keys K_a with limited validity period by KMS to all legitimate units
- CBC-MAC Code based on K_s is calculated and used in radio packets.

21

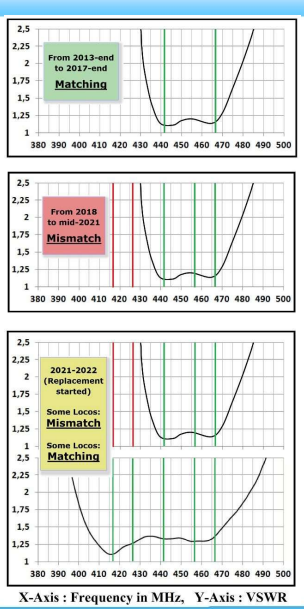
Authentication Key to Kavach (TCAS) Entities through KMS



22

Experience of RF Communication in R&D Field Trial Section

- Basis for initial adoption of 441.8, 466.8 MHz for R&D
- Basis for 30m Tower Height for R&D Section
- Era of mismatch among frequency range in use and centre frequency of antennae
- Allotment of 05 freq channels for further use in Kaavch 427.625, 427.875, 428.875, 429.525 and 429.800 MHz
- Feasibility of closely spaced 09 frequency channels – 04 in addition to 05 already allotted.



X-Axis : Frequency in MHz, Y-Axis : VSWR

23

Conclusion

- An ATP as overlay on an underlying signalling system needs exchange of lot of data on realtime basis.
- Kavach would not have possible without mComm
- mComm supports open protocols and direct onboard-to-onboard communication.
- It is secure, highly spectrum efficient, realtime and adaptive to train traffic density with requirement of just optimum number of frequency channels for that region.
- mComm triggered the commencement of development of Indian Railways' indigenous cab-signalling ATP without waiting for LTE.

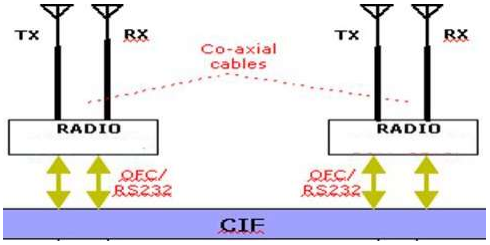
24

Thanks for Watching

Lalit Mansukhani, IRSSE (NF-HAG)
OSD/Centre of Excellence, Secunderabad
(+91 9701518800)

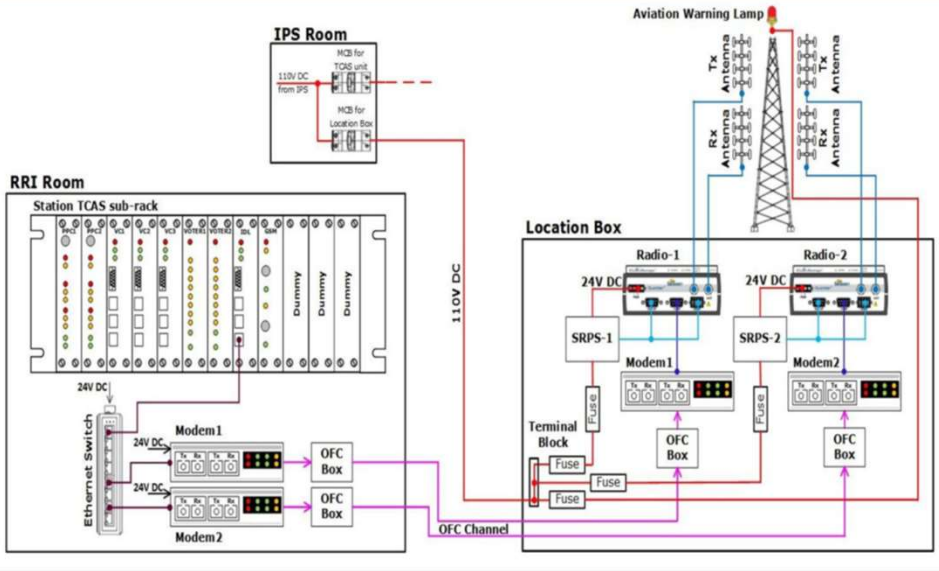
25

Radio Payload Communication



26

Radio Communication : Schematic

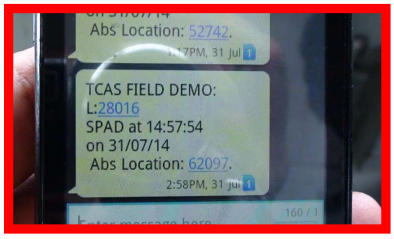


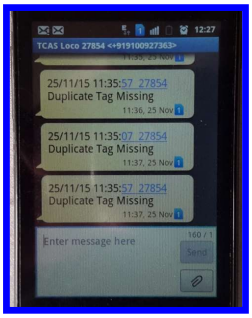
27

MComm Radio Communication Antenna

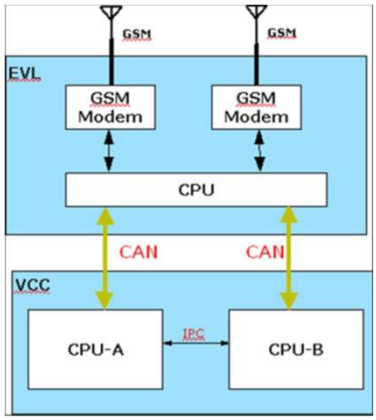
28

Kavach : GSM- GPRS

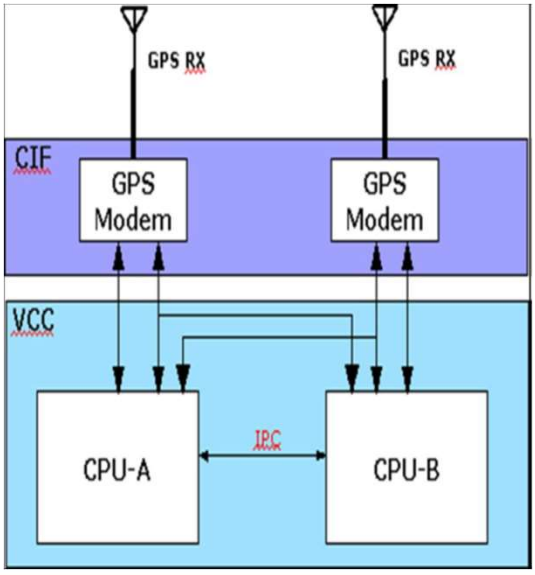




- **Prompts and SMS Alerts on various events**
- **To get Security Keys from KMS**



Kavach : GNSS – GPS Interface



30