TRAI

सत्यमेव जयते

Report on

Mobile Network QoS

Delhi Airport and Dhaula Kuan

Telecom Regulatory Authority of India

March 05, 2019

In case of any comments regarding the report, it may be sent to the following address:

Shri Asit Kadayan,
Advisor (QoS),
Telecom Regulatory Authority of India (TRAI), Mahanagar Door Sanchar Bhawan,
J.L. Nehru Marg, (Old Minto Road)
New Delhi - 110002, India
Email: advqos@trai.gov.in

For any clarification/information, Advisor (QoS) may be contacted at Tel. No.+91-11-2323-0404, Fax: +91-11-2321-3036.

Mobile Network Quality

Delhi Airport and Dhaula Kuan

Executive Summary

Hon'ble Prime Minister observed that the network quality was poor in the on the route between Delhi Airport and Dhaula Kuan and that there were incidences of call drop in this area. He desired that all solution, including technological ones, may be explored to overcome this problem.

For a detailed assessment of the problem, multiple drive tests and general inspections of the area (including all approaches, the terminal buildings, airport apron area, etc.) were undertaken by TRAI. The deficiencies that were identified and the action required to address the concern of poor quality of service are presented in this report.

It was observed that, in general all service providers, except MTNL meet the statistical benchmark specified for Drop Call Rate (DCR) for Delhi Licensed Service area. However, users may experience poor quality of network in certain patches of roads and within the airport buildings. This **poor quality is linked to infrastructure deficiencies** in the area, for which agencies, such as GMR, Ministry of Civil Aviation, Ministry of Defence (MoD), etc., are also required to act in support of the telecom service providers.

Agencies, such as GMR, MoD, or DMRC, enter into contract agreements with third-parties to install and operate common infrastructure. This is done on basis of a competitive bidding process. The telecom service providers obtain services from these third-party infrastructure providers that have monopoly power by virtue of the contract already won. The monopoly conditions impedes investment in upgrading or expanding the infrastructure and makes access to services very expensive. A change in the process for selecting third-party infrastructure providers and revision of the terms of their contract are two urgent measures required to address the infrastructure deficiencies that were noticed. The agencies governing specific areas need to play the role of a facilitator and own the responsibility to maintain QoS. They need to develop a mechanism which ensures that third-parties having exclusive rights to provide infrastructure also meets the QoS requirements. Suggestions in this regard are given in the report.

The **Telecom Service Providers** are required to coordinate with the appropriate authorities for permissions and to pursue the matter in case of pendency. They need to find or develop innovative radio network solutions for meeting specific requirements of Airport area where there are constraints on locations or maximum height for the cell towers. They also need to deploy towers and antennas which blend aesthetically with the building and surroundings where they are installed. This would bring greater acceptability among building owners/ management. TSPs are also required to carry out more exhaustive testing of the area and on more frequent basis.

Department of Telecom (DoT) need to revisit provisions related to licensing which makes Infrastructure Providers (IPs) responsible for maintaining, upgrading and expanding the network in a timely manner. It is also required to coordinate among the agencies governing specific areas that grant permission to deploy infrastructure, including the Defence Ministry and Airport Authorities.

TRAI may conduct similar tests and general inspection of various other Airports and large public buildings to identify similar issues where action is required by multiple agencies to improve mobile network quality.

1 Background and approach for assessment

1.1 Terms and Reference

Department of Telecommunications (DoT) on September 27 of 2018 referred[1] to Telecom Regulatory Authority of India (TRAI) regarding observations made by Hon'ble Prime Minister of India, about exploring/ leveraging all **technological solutions** to effectively tackle problems of **poor network quality** and call drops with specific reference to poor network quality on the route between the Delhi Airport and Dhaula Kuan. It was also asked to make efforts to ensure **proper and full coverage** along this route on priority as number of **International tourists use this route**. Vide this reference, it was also sought to identify specific problem areas so that **Department can take remedial measures** to put in place.

1.2 Meeting with TSPs to understand issues and take remedial measures

In this reference, TRAI met, on 8th of October 2018, with all the concerned mobile network operators to share their assessment of the quality of mobile networks in the area and to understand, in general, the key issues. Subsequent to this testing of the area was carried out and general inspection was done by the TRAI in the association with the mobile network operators during October 10 to 16 and during October 30 to November 01. After conduction of tests and inspections, TRAI again met on 26th of November 2018 with all the concerned mobile network operators to discuss with them the quality related issues observed during testing and remedial measures required to resolve the issues and efforts required to ensure proper and full coverage in the area.

1.3 Types of Radio Networks deployed to serve the area

In Delhi Airport area, mainly there are four mobile network operators namely Airtel, MTNL, RJIO and Vodafone-Idea who are providing mobile services. They have deployed different types of radio access networks such as GSM (2G), WCDMA/ HSDPA (3G) and LTE (4G). These radio networks are using various spectrum bands such as 800 MHz, 850 MHz, 900 MHz, 1800 MHz, 2100 MHz and 2300 MHz. Deployed Type of Radio Access Technology(ies), Spectrum Band(s) and Bandwidth in a particular spectrum band may vary from one mobile operator to another mobile network operator. In Building Solutions (IBS) deployed in the terminal building areas are not supporting all of the Radio Access Technologies and Spectrum Bands which an operator is operating in the outdoor networks.

1.4 Conventional Approach to Assess the Quality

Mobile network quality in terms of coverage and capacity, is dependent upon radio access technology, spectrum band, available bandwidth in the spectrum band and extent of

[1] Letter no F. No. 5/Misc. Secy. DOT dated Sep 27, 2018 from Secretary DoT to Chairman, TRAI

densification of radio networks. Typically, to assess the quality of network in an area, field measurement tests are conducted with appropriate tools while driving along the routes known as Drive Test. Assessment is done by measuring Key Performance Indicators (KPIs) such as network signal strength, quality and measuring retainability of voice calls which are made for a specific duration and maintaining a gap between two consecutive voice calls. To quantify outcomes for each KPI, ratio of number of good samples to a total number of samples is taken. Network quality is assessed on the basis of percentages achieved for these KPIs. For IBS, similar KPIs are assessed while conducting tests in various parts of building and floors known as Walk Tests.

1.5 Approach adopted to assess the quality in the instant case

To ensure proper and full coverage, it was felt that Drive Tests and Walk Tests are required but to identify key issues from users' perspective in a more effective manner and also to identify specific actions required for improvements, general inspection of area is very important. General inspection of area enabled to make inferences about the state of quality of network and its impact on experiences of the users in typical situations. Remedial measures including technological and innovative solutions which may be leveraged are also deliberated in relevant paras of this report along with the key issues observed while inspecting the area.

2 Delhi Airport area and ecosystem providing mobile services

2.1 Description of Landscape and Buildings in Delhi Airport Area

Delhi airport area includes Indira Gandhi International Airport (IGIA) and Domestic terminals which is spread over an area of 5106 acres[2] (2066 hectares). The airport area also has built up area such as four terminal buildings namely T1, T2 and T3 for passenger traffic and one terminal for cargo purpose. The built-up area also includes other buildings such as Udaan Bhawan, ATC towers, Delhi Police Station, Common Distribution Facility (CDF) for IT and Telecom Equipment, BCAS office, New Custom House etc. and various Hotel Buildings including Centaur Hotel & Aero city hotel buildings. These buildings house many users of mobile networks and have a potential to provide infrastructure to establish mobile radio networks. Out of all these buildings, T3 terminal is the biggest one among all and it is spread over an area of 20 acres[3] (8.1 hectares).

2.2 Mobile users in Delhi Airport Area

Delhi Airport has stated capacity to handle 62 million passengers per annum[4] (mppa) while

[2] https://www.newdelhiairport.in/igias-t3-becomes-first-platinum-rated-green-airport-terminal-building-in-india.aspx

[3] https://m.newdelhiairport.in/pr-IGI-Airport-Engineering-a-Marvel.aspx

[4] https://www.timdaa.com/overview.php

about 65.7 million passengers[5] have been handled during year 2017-18. In the month of October 2018 only, it has handled more than 5.8 million passengers[6]. Typically, 40 to 50 thousand persons other than the travelers such as ground staff of air lines, security personnel, persons working on retail or Food & Beverages (F&B) outlets etc., visits the airport area. Number of mobile users in terminal area may be broadly estimated from the number of persons in these areas. While assessing the network quality in airport terminal buildings, considering the requirement of users who are not passengers but work in the area may also be important as these persons provide support services to the passengers. It is also important to note that radio network capacity is shared among all types of users.

2.3 Challenges in deployment of radio networks peculiar to Airport Area

Largely, Airport area is an open field with sparse buildings and on first sight seems to be easy task to get covered by mobile radio networks as it offers free space propagation without any obstructions. However, there are constraints on the deployment of towers in the area in terms of height and locations because of conditions imposed by requirements of civil aviation. To cover entire area in a full and proper way under the constraints imposed in terms of height and location, a greater number of sites may be required in comparison to cover this type of open area without such restrictions. To provide coverage in built-up areas, especially terminal areas requires implementation of radio network in-building solutions. In-building solutions for these areas may require deployment of huge number of antennas and laying of cables, electronic and radio equipment to provide coverage and capacity as per the size of the building, number of users present in the building.

2.4 Role of other actors than TSPs in deployment of the radio networks

To deploy network infrastructure in these areas may require permissions and support of various agencies responsible to operate and manage these areas. In this regard few of the most import agencies are Civil Aviation authorities, Delhi International Airport Limited (DIAL) and Ministry of Defence (MoD). To deploy in neighbourhood areas of airport such as cantonment area, permissions and support of Ministry of Defense (MoD) and Air Force Authorities may be required. To deploy network in Airport area, permissions may be required from DIAL/GMR. DIAL is a joint venture, formed as a consortium led by GMR as GMR Group has highest share[7] of 54% in comparison of other members such as Airports Authority of India (26%), and Fraport AG & Eraman Malaysia (10% each). Integrated passenger terminal (Terminal 3) was inaugurated by the DIAL in March 2010. DIAL entered into Operations, Management and Development Agreement (OMDA) on April 4, 2006 with the AAI. The initial

[5] https://www.timdaa.com/overview.php

[6] http://knowindia.net/aviation3.html

[7] https://www.gmrgroup.in/dial/

term of the concession is for 30 years extendable for another 30 years.

2.5 Same network but different users experience different quality

Impact of poor quality of services in terminal areas is felt differently by the passengers arriving on the airport viz-a-viz passengers departing from the airport. Experiences of a user is also dependent upon the time spent in the area offering good or bad network quality, journey time after which one would get next chance to connect, immediacy of the work to be finished via mobile networks etc. Therefore, experience for a person travelling to an international destination or to a domestic one may not be same. It will be because of time spent by a passenger departing from the airport to take an international flight or passenger in transit waiting to connect to next flight is different than other types of passengers. Some passengers may stay in terminal area for a period of few hours to maximum 24 hours and may be staying in hotel or sleeping pods available in the terminal area itself. For data connectivity, there are alternatives such as Wi-Fi networks, but in certain situations, users may prefer to get connected via mobile networks than a Wi-Fi network as it involves a cumbersome process to log-in to a Wi-Fi network and requires repetitively to be logging in. Passengers arriving via flights use mobiles in different parts of terminal area and their stay period is relatively much shorter.

2.6 Need to analyze issue at a sub-area level and experience of different user segments

In view of above, for getting comprehensive perspective of the quality of service in the area under reference, it would be useful to examine the issue by dividing the area into four sub-areas namely Runway and Apron Area, Terminal Area, Road Routes and Airport Metro Route. Assessment of the quality of service in the area, requires that adequate infrastructure is in place to serve the demand of these four sub-areas. Adequacy is determined by assessing the demand side requirements such as the number of users, mobility, service usage etc. viz-a-viz the supply side availability such as coverage and capacity of the mobile networks. Next four paras describe and deliberates on specific issues related to a particular sub-area. Subsequent to these paras, observations, analysis and suggestions have been summarized.

3 Assessment in Runway and Apron Area and actions required to improve quality

3.1 Description of Runway and Apron Area

Delhi airport has three runways[8] namely Runway 11-29 in southern part of the airfield, Runway 10-28 and Runway 9-27 in northern part of the airfield. Runway lengths are of the

[8] https://www.newdelhiairport.in/fact-sheet.aspx

order 2.8 to 4.3 kms and typically spread in open area which is 1 to 1.5 kms wide. There are number of apron areas namely 31 to 35, Domestic apron, cargo apron, maintenance apron, satellite apron etc. There is a technical area adjacent to the Runway 9-27 which is used for VVIPs and also for some designated persons or for some specific purposes.

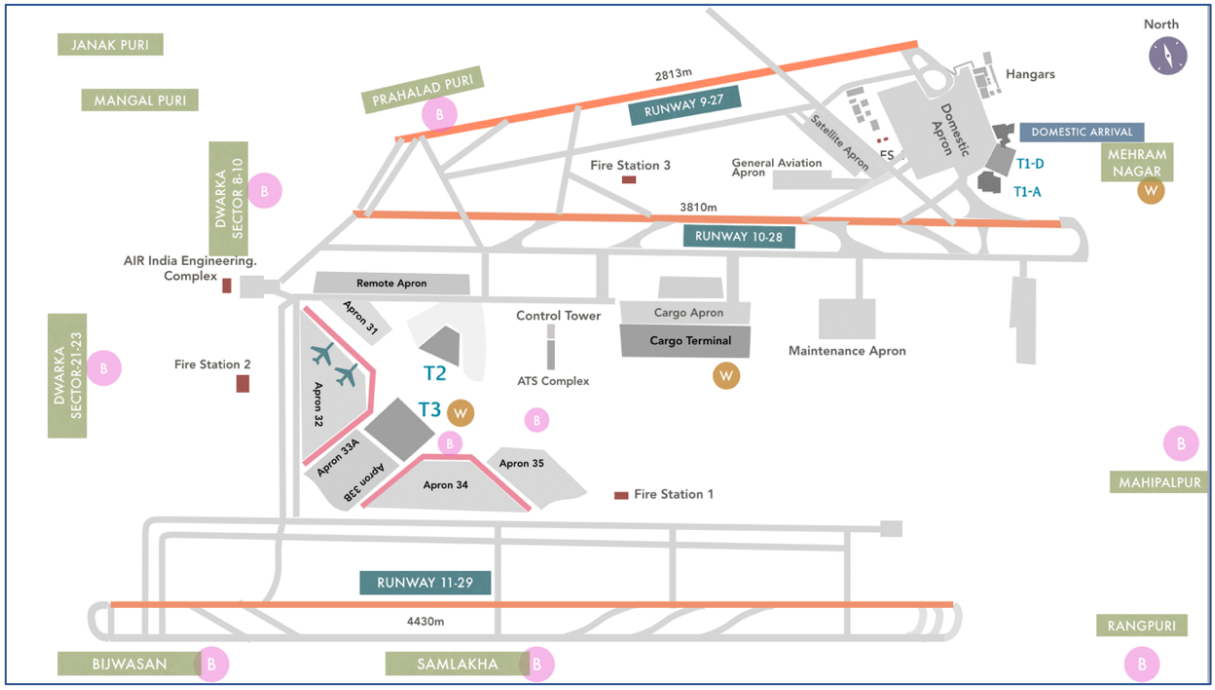

Figure 1: Delhi Airport Area

All three runways and all apron areas are interconnected through taxiways and service lanes. In general, this area is very large open and free space area, but its shape is an irregular polygon. There are numerous grass land area pockets which are not used as such by aircrafts or ground transports.

3.2 Current Set up of Radio Network Serving the Area

The runway 11-29 area is being served by the base stations located in habited area in neighborhood of airport such as Dwarka sector 21 to 23, Dwarka Sector 8 to 10, Bijwasan, Samlakha, Jat Shahpura. The runway 10-28 and runway 9-27 are served by base stations located in habited areas in neighborhood of airport such as Prahlad Puri, and Cells on Wheel (CoW), which is a temporary infrastructure and located on sides of Northern Access Road near to cargo terminal and in Cantonment area. Apron areas are served by the same outdoor sites (base stations) which are serving runway areas, but the apron areas are at edges of coverage area of these sites and practically poorest quality region of serving area of any site.

3.3 Challenges in deployment of radio networks peculiar to Runway and Apron Area

Such open areas are easy to cover with fewer sites (by radio networks transmission towers also known as base stations) as there are no physical obstructions for radio waves to propagate from antenna to the user. More sites in the vicinity causes interference due to

multi-server problems as radio signals from multiple sites are there. Fewer sites limiting its radiating powers to confine within desired serving area and to avoid interference to neighboring sites cause another problem that is of poor signal strength at the edges of the cells. Currently, this area is covered by outdoor sites which are located outside the airport premises area i.e. in the neighborhood habited areas. Sites not located within airport premises area to serve this area is mainly due to usually not granting permissions by the civil aviation authorities to install the transmission towers inside such areas because of some operational restrictions in the area. Serving more users which are located at the edges of cells, not only delivers lower throughput but it also leads to poor utilization of radio resources and thereby reducing overall cell throughput. In result, even the users which are nearer to antenna do not be getting better throughput which they may get otherwise. Serving users by sites closer to them would give better experience to the users not only in terms of throughput but also lesser consumption of battery which is especially important from a traveler's perspective.

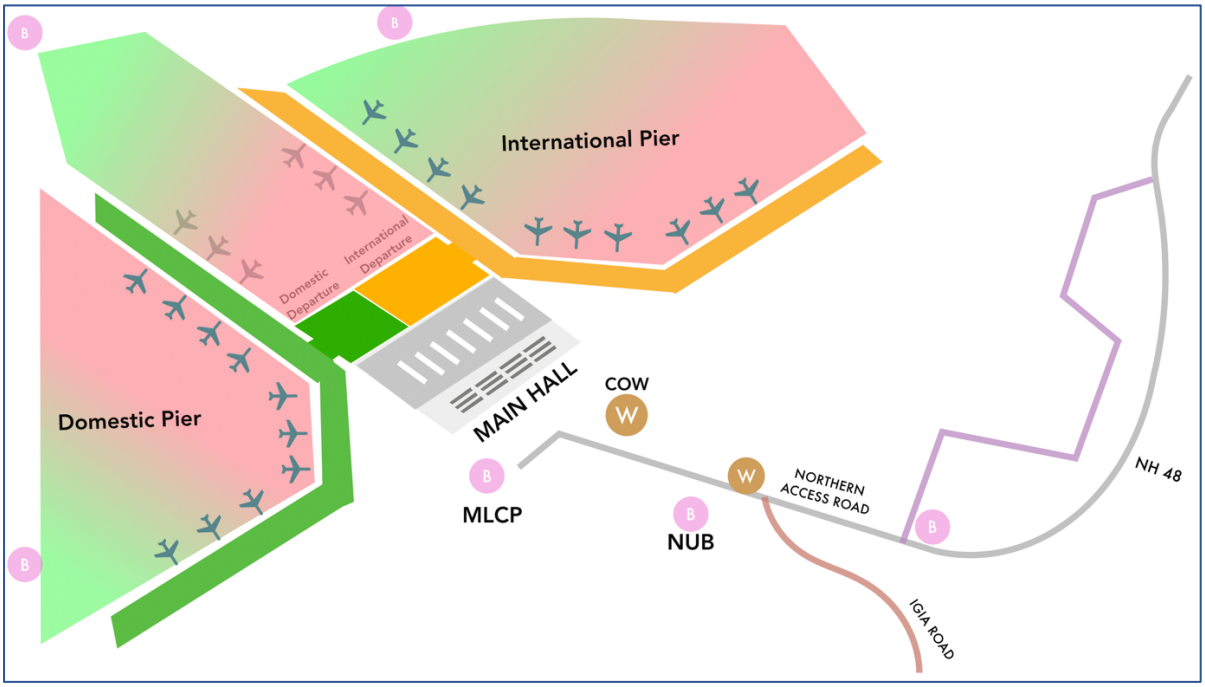

Figure 2: Coverage in Runway and Apron Area

3.4 Options to improve the quality of service

There are buildings inside the region of runway and apron area such as four Fire Stations (FS1 to FS4) and Air India Engineering Complex. If antennas are permitted to be installed on these buildings and backhaul connectivity is provided for then quality of service in these areas can be greatly improved. Special radio network solutions which are customized to serve the purpose in such type of situations are required to be built and deployed. These solutions can

be of very low height from ground and can be located in grass part of the area causing no harm to operation and management of civil aviation systems. Considering rare presence of persons in neighborhood areas of locations of such radiating elements, may not cause any concern of Electro Magnetic Field (EMF) radiations as such.

Second option may be to permit mobile network operators to radiate with more emission powers (EIRP: Emitted Isotropic Radiation Power) than prescribed maximum limits for EIRP in normal scenarios. It can help to serve the area by deploying different types of antenna such as directional antennas, wider beam width antennas. Third option may be to permit to install antennas on outer walls of terminals and specific points on the aerobridges. Any installations inside the runway and apron areas, not only requires permissions to install the equipment and backhaul connectivity but also access permissions for staff of mobile network operators to visit these areas on regular basis for maintenance and in case of an emergency.

3.5 Adoption of latest technological solutions to handle surges in traffic

Mobile traffic behavior in cells of base stations serving runways and apron area is quite different than normal sites installed elsewhere. These sites do observe surge in demand when aircraft lands and approaches towards apron area or just before dis-embarkment. Or it sees surge in the traffic during embarkment period of the aircrafts getting ready for departure. Airport traffic statistics indicates that every day on an average for all three runways about 1200 aircrafts movements[9] takes place. Out of this about 600 aircraft lands and 600 aircrafts takes off. It means on average, approximately every minute either an aircraft lands or takes off from the one of the runways. This might be leading to surge of signaling traffic to latch on the network which is carried out at the time of powering on the mobile handsets. Powering on by hundreds of mobile handsets within a short time span in same radio network cell might not be observed in other normal cells of the network. Subsequent to this, there may be traffic of short duration multiple voice calls or OTT (Over The Top) communication applications traffic. As aircraft moves towards apron area, this traffic is handed over across multiple sites. This type of traffic can be handled in a more effective manner, if latest technology solutions are used such as cloud-RAN (Radio Access Networks), smart Antennas to form beams towards actual location of users.

3.6 TSPs need to make regular Assessment of quality in areas difficult to access

During testing and inspection of this area to assess the quality of service, it was observed that it was the first time, that mobile network operators were conducting tests to ascertain the situation. Even with the currently deployed infrastructure, services can be improved by optimizing it on the basis of feedback from the outcome of network coverage testing in the

[9] https://www.aai.aero/sites/default/files/pr_articles_clippings/press_clippings_dt_14.10.17.pdf

area. When enquired from the representatives of telecom operators, it was found that they never approached relevant authorities for granting the permissions and necessary support to conduct the tests. We are thankful to GMR, Airport Authority of India (AAI) and Pass section to grant permissions and necessary support to conduct tests in runway and apron area. But it is also a fact that such permissions and arrangements were made on a special request from TRAI. There is requirement to set up a procedure by the GMR in collaboration with TRAI and Telecom Service Providers to conduct such testing at least twice a year.

3.7 TRAI's initiatives which would help in alleviating impact of poor network quality

TRAI has sent the recommendations on in-flight connectivity to Government of India on 18th of January 2018 and same have been accepted. Ministry of Civil Aviation may expedite its implementation and endeavor to make it available in most of the flights operating from India. Though, enablement of this connectivity may not be directly helpful to improve quality of network on runway and apron area but offering services during journey time may probably help to avoid surge in traffic demands immediately after arrival of flight and it would also reduce time gap between network non-availability at the time of air travel. However, real advantage may be dependent upon the tariffs of such services.

4 Assessment in Airport Terminals Area and actions required to improve quality

4.1 Description of Airport Terminal Area

Delhi Airport has three passenger terminals namely T1, T2 and T3. It has one cargo terminal. Terminal 3 (also known as T3) is a biggest among all terminals in terms of built-up area and also in term of mobile users in the terminal building. Two-tier building with the lower floor being the arrivals area, and the upper floor being a departures area. T1 and T2 being domestic airports and catering to much less passenger traffic are largely single tier building and spread to much smaller area than T3. Radio network solutions for T3 is active in-building solution while in case of T1 and T2 it is passive in-building solution. In case of Cargo and technical area, radio signals pilferage from outdoor sites to inside the buildings is providing coverage. First entry point of T3 terminal for passenger departing from airport is check-in counter area. Check-in hall is a big hall and has 168 check-in counters for different airlines. T3 terminal has about 78 aerobridges, 48 contact stands and 54 parking bays.

4.2 Mobile Users in Airport Terminal Area

Total capacity of Delhi Airport infrastructure is about 62 Million Passengers Per Annum (MPPA), out of which T3 terminal has capacity of 34 MPPA[10], T2 terminal with 12 MPPA and

[10] https://www.newdelhiairport.in/gmr-led-dial-set-for-delhi-airports-expansion-in-line-with-master-plan.aspx

T1 terminal with 16 MPPA. Peak capacity of total passengers combined for T3, T2 and T1 goes beyond 10,000 passengers per hour. Most of the passengers are mobile users and use voice as well as data services for communication, information and entertainment purposes. Cargo terminal handles about 0.9 Million Tonnes Per Annum (MTPA), however number of mobile users are quite insignificant in comparison to passenger terminals and as focus of the current study of issues was on air travellers, in-building area was not included for testing and inspection. Mobile network connectivity to other persons on terminal who are not passengers as such is also important as far as services used by the passengers at the airport terminal, however it may not be directly related. In view of this, all floors of terminals with almost all of its area were included for purpose of testing and inspection.

Among all terminal buildings in Delhi Airport area, T3 terminal is a biggest one. It is a seven storeyed building with majority of passengers mainly on floors of departure and arrival levels. Other levels of building are also be used by passengers e.g. Food Court, Lounges, Hotel (on top floor). While going from a particular floor to other floors, they are using services from networks available at other floors though use may be for a very short period. All floors including departure and arrival floors, are also used by Airline staff, security staff, shopkeepers, food court staff, lounge staff and other supporting staff. T1 and T2 terminal buildings are much smaller in area and having only two floors. Issues of mobile network quality inside the terminal T3 are discussed and deliberated first and issues related to other terminals are discussed subsequent to it.

4.3 Current set up of Radio Networks for T3 Building

T3 terminal building is served using In-Building Solution (IBS) with 12 sectors of radio network serving different parts of the building. To cover entire building including all floors, about 1400 antennas have been deployed. Radio network coverage plan seems to be well designed as far as number of antennas and their locations is concerned. Radio network traffic of all these sectors have been aggregated to a common distribution point located outside terminal building area known as IT Utility Equipment Room. All mobile network operators are given connectivity to indoor infrastructure via a special equipment installed in IT Utility Equipment Room. The equipment in this room, electronic equipment installed in the terminal building area, cables, splitters, combiners etc. are spectrum band specific and have specific issues related to a particular radio access technology such as WCDMA, LTE etc.

Mobile network inside T3 building is provided using in-building solutions operated and maintained by WASIL who is a registered Infrastructure Provider (IP-I). WASIL is a joint venture of GMR/ DIAL and Wipro. WASIL has outsourced operation and maintenance function to company Celkom.

In areas of check-in area hall nearer to glass panel wall, mobile network signals from outdoor sites such as Site on Muti-Level Car Parking (MLCP) building and Cell on Wheel (CoW)

deployed just outside, in front of main entry point are available to the user.

4.4 Issues with IBS at T3 regarding support of spectrum bands and LTE

It was observed that the connectivity for LTE operating in 2300 MHz band has not been provided by in-building solution provider. Even mobile operators having WCDMA network in 900 MHz bands are not supported by current electronic equipment of in-building solution. Due to this radio networks operating inside terminals are not same as of outdoor areas. This has impacted radio network capacity offered to the users. LTE operators such as RJIO having LTE in 2300 MHz band and in 850 MHz band are providing services only in 850 MHz band. Bandwidth available in 850 MHz band of RJIO network is limited to 5 MHz. Airtel and Voda-Idea networks are offering LTE networks in 1800 MHz with limited bandwidth. MTNL is not having LTE network and is offering data services via WCDMA and HSPA networks. Experience to the users of same mobile network operator is sometimes quite different depending upon support of particular spectrum band in their mobile handsets.

4.5 Issues of upgrading, expanding and maintaining IBS at T3

Mobile network operators on its own are not in a position to improve the quality of IBS network getting deteriorated due to ageing causing issues like higher Passive Inter-Modulations (PIM) and higher losses. Impact of deterioration of IBS on quality is dependent upon radio access technologies and spectrum band. Timelines, of network upgradation, expansion and upkeep of deployed infrastructure is entirely governed by the GMR/ DIAL or its joint venture WASIL. Mobile network operators have no say in setting these time lines and priority. Mobile network operators already having connectivity, would have been in a position to enforce their requirements, if they would have made such requirements as part of their contractual agreement with the infrastructure provider. However, infrastructure provider has upper hand over mobile network operators as there are no other options with TSPs have to provide services inside the terminal building. Taking a chance not to enter into the agreement may result into revenue loss to the mobile network operator and may also result into its customers churning out to competitors.

Current in-building solution was deployed in year 2007-08 and has not been upgraded thereafter. LTE technology in all spectrum bands as such and WCDMA in 900 MHz was not part of the plan of the in-building solution. All mobile network operators are dependent upon solution deployed by WASIL (Operated by Celkom). Healthy condition of system, sector and antennas is supposed to be monitored by Celkom. Any fault at antenna level is not directly detected by system and comes into notice only when somebody reports it. Passengers are less likely to report no coverage or poor quality of network signals in any particular part of the building as they stay there for a very short period and are not aware about the number where complaint is to be made.

4.6 Rent seeking practices in current model of selection of Infrastructure Provider

Typical requirement by GMR/ WASIL for a mobile network operator to provide connectivity is to deposit security amount running into range of one Crore Indian Rupees and pay rent on monthly basis which is in the range of 40-45 Lakhs INR. In addition to it, Mobile Network Operators have to pay at the stage of expansion such as from 7 sector to 12 sector in-building solutions. Typical arrangement for discovery of price at which such agreement are made is based on H1 (Highest Bidder Model) i.e. selection of single infrastructure Provider to deploy in-building solution on which other mobile network operators would ride and offer their services is based on highest bidding process. The single Infrastructure Provider gets exclusive rights to give connectivity to mobile network operators and at a price point determined by it. In this process, focus is on revenue maximization by entity selecting and awarding rights to Infrastructure Provider and in turn rent seeking by the Infrastructure Provider.

Figure 3: Air Side and City Side of T3 Terminal Building and Inner Core Part of the building

4.7 Need to analyse T3 Building in two parts

In general, for the purpose of analysis of quality issue, terminal building need to be divided into periphery area and core inner part of building. Peripheral area of building is outer part of the building where network signals from outdoor radio network sites are also available in addition to the network signals of in-building solutions (IBS). Core inner part of building is part of building excluding peripheral area and where signals of in-building solutions are available only. Peripheral part need to be further divided into area of building facing towards city side and area facing towards air side. The division of building areas into periphery and core area

gains important because of the gaps in the capabilities of outdoor sites and IBS in terms of supported spectrum bands and radio technologies. Division on basis of “city side” and “air side” of terminal building for quality of service makes sense because of typical distance between the users and the outdoor sites. On city side, sites are closer to user as they are installed on neighbouring buildings within Airport area. On air side, typical distance of outdoor sites are quite far as radio network sites are located in neighbourhood habited area which is outside airport premises with a large gap due to runway and apron areas. On peripheral part, quality of signals are also be dependent on level of floor as radio signal strength from outdoor antennas do change significantly with height.

4.7.1 Core area and Peripheral area of the T3 Building

Immigration area, custom area, food courts, Duty free shopping area, part of security hold area, baggage reclaim area etc. falls under inner core part of the building. Foyers at departure and arrival floor, check-in hall at departure floor, Meet & Greet (M&G) Area are city side peripheral part of the terminal building. Hotel located on 5th floor and some of airline offices are on air side peripheral part of the building. Most of International and domestic piers areas falls into peripheral part. Longer side of this area is towards city end, while other side of the area is towards air field.

4.7.2 Mobile Network Quality related Issues in T3 Building Core area

Antennas are located across the hall to cover the hall and during testing, coverage was found satisfactory. However, it was found that test tools of the mobile network operators are not equipped with the digital map of layout of floor(s). Due to this, after conducting tests it was not in practice to generate radio network coverage map of floor. Detailed coverage map for floors for different spectrum bands could have facilitated to identify issues in particular pockets of floor. GMR/ DIAL and Mobile Network Operators are required to coordinate to make available desired digital maps and antenna layout plans to all stakeholders. This will help in better assessment of mobile network quality.

4.7.3 Mobile Network Quality related Issues in T3 Building Peripheral area

Due to spectrum band and technology specific issues inside the building area, quality of services is sometimes quite different in the part of the hall nearer to glass panels in comparison to other parts of hall. Similar issues are observed on peripheral areas where coverage from outdoor sites and in-building area overlaps. But this is more dominant in the International Departure Pier and Arrival Pier Areas as these are wing shaped and have widths which are relatively narrower than other part of building. In this part of the building, glass panels are on both sides and provide connectivity to gates and apron area. One side of the pier area is closer to outdoor sites located at MLCP building and other side of pier area gets signal, though weaker in the strength, from outdoor sites located outside the premises of

airport and are in neighbourhood habited areas such as Bijwasan, Smalakha, Dwarka etc.

In middle part of pier area, in-building network signals dominates. Passengers also use Sleeping Pods available in International Departure Pier Area to stay for longer period. Meet & Greet (M&G) Area on arrival floor has similar issue as in case of check-in area of Departure floor, but stay period of passengers in M&G area is very short in comparison to check-in area.

Figure 4: Antennas at roof top of Multi-Level Car Parking (MLCP)

Mobile network quality on aerobridges would vary quite significantly as some areas are being served from sites located remotely, while in other cases area is closer to outdoor sites. User movements across the cell edge boundaries of multiple site area also leads to multiple handovers and also altogether different quality of service depending upon which site is serving to.

Situation of Domestic pier area of T3 terminal is quite different than situation of International Pier area. Domestic Pier area of T3 is closer to T2 terminal building and signals of mobile network operators who have installed sites on roof top of T2 building with antenna oriented towards this pier area have better coverage than others.

Hotel, which is used by passengers in transit, is located within terminal building and is situated at fifth floor. It is located in part of terminal building which is closer to the apron area 33B, this area is served by in-building solutions and outdoor sites located 1 to 1.5 kms away. Feedback on quality of network was taken from Hotel receptionist and security personnel, and key issue was related to poor data throughput. Situation of mobile network quality for airline offices located at 2nd to 4th floor in the same section of building is more and less similar to hotel.

Main foyer of terminal 3 building and area where passengers usually pick up taxis or personal vehicles is served mainly by COWs (Cells on Wheel) located on opposite side of road and also

by outdoor sites located at top of MLCP (Mult-Level Car parking). COWs are temporary arrangements for providing network coverage and agencies granting permission sometimes ask suddenly to remove it. Coverage inside MLCP building which provides parking facility for more than 4300 cars[11] and also provides space to App based taxi services such as OLA and Uber is poor as it is not covered by in-building solutions.

Figure 5: Cell on Wheels (CoWs) in front of T3 Terminal

4.8 Quality related issues in Terminal Buildings T2 and T1

In case of T2 and T1 terminal buildings, similar problems exists which arise out of H1 (highest bidder) model to select Infrastructure Provider and then award exclusive rights to it and rent seeking while provide connectivity to mobile network operators. One big difference in case of these buildings is that the built-up area of these buildings is very small in terms of land area and also in terms of number of floors. From Radio signal propagation perspective, it becomes relatively easier task to reach out in different parts through passive type of in-building solutions. In many parts of these buildings, coverage from outdoor sites is also available. Moreover, number of users being much less than in case of T3, radio network capacity requirements is much less and can be met even when all spectrum bands for same technology

[11] https://www.neptuneautomatic.com/parking-management/delhi-airport-t3-parking/

radio networks are not available. Both terminals being domestic terminals, stay period of passengers is smaller than in case of International terminals.

4.9 Actors other than TSPs need to collaborate with TSPs to improve quality

It is required to keep in mind that services offered to air travellers passengers by air lines, airports, cab providers, metros etc. are getting more and more dependent on telecom networks. In upcoming times, 5G networks would be deployed which offers solutions to different industry verticals including civil aviation sectors. Timely upgradation and expansion of latest technology radio networks would not only offer advantages to air travellers but it would also benefit to civil aviation and associated actors in bringing efficiency and effectiveness to their operations and management.

It may be noted that industry was aware about the deployment of LTE networks in India as spectrum for Broadband Wireless Action (BWA) was being finalized in year 2008-09 and it was auctioned by DoT in year 2010. In Delhi, LTE based network was commercially launched in September 2016 but its roll out started much earlier. Infrastructure providers for in-building solutions, especially in large public building areas are supposed to track the new radio access technologies being introduced in the market and plan for upgrading their networks in timely manner. Even after massive scale deployment of LTE networks across the country and significant penetration of LTE users, there seems to be no concrete plan of GMR/DIAL/WASIL to upgrade their systems and solutions to support LTE technology. Collaboration among Infrastructure Providers and Mobile network operators could have changed the situation and pushed to act in advance rather than acting several years after roll out of technology in outdoor areas. Platform need to be created for relevant stakeholders to interact on a regular and formal basis where upcoming requirements can be finalized and time lines for implementation may be set.

4.10 Implementing TRAI recommendations on IBS to improve quality in Terminal Building areas

Mobile network quality issues observed in T3 building area can be improved immediately, if in-building solution is upgraded to support LTE and WCDMA for all spectrum bands operating in Delhi area. TRAI on 20th of January 2017, sent its recommendations on “In-Building Access by Telecom Service Providers” to Government of India and key points were to mandate Infrastructure Providers to share access on fair, transparent and non-discriminatory basis. It also mentioned that Common Telecom Infrastructure (CTI) in large public buildings in accordance to the prescribed standards is in place. Government of India has yet to accept the recommendations. Implementation of this recommendations would be useful to avoid situations where Infrastructure provider is willing to make exclusive arrangements limited to certain mobile network operators. However, there is need to work on a mechanism for determination of “fairness” and “in accordance to prescribed standards”.

4.11 Option to prescribe QoS Standards for Infrastructure Providers

One of the option may be to define and apply Quality of Service (QoS) standards on Infrastructure Providers. These standards of QoS for IPs may become integral part of Service Level Agreements (SLAs) between Mobile Network Operators and Infrastructure Provider. Alternatively QoS standards may be enforced via regulations directly applicable on such Infrastructure Providers. There may also be a need to prescribe ways and means for Infrastructure Providers and Mobile Network Operators, as and when required to upgrade and expand in-building systems in a timely manner.

4.12 Owner or Controller of Building or Area need to own responsibility to maintain quality

To provide uniform and good mobile network quality inside terminal building areas, it is necessary to bridge the gap between capabilities of IBS and outdoor sites. IBS has to be upgraded, expanded and maintained to support all spectrum bands and radio technologies as available in other parts of service area. Providing such capabilities and supports at a fair price point and make available it in a timely manner requires formal collaborative set up among infrastructure providers and mobile network operators. This mechanism needs legal backing via appropriate contractual agreements, changes in conditions of licenses and regulations for all types of service providers. To maintaining desired quality of service inside the building requires periodic measurements and generate post processed coverage and quality maps over digital floor layouts. Quality of Service regulations specific for this purpose may also be framed to monitor and ensure desired quality of services. It is necessary to change current H1 based business model to select single infrastructure provider and give exclusive rights without much obligations to maintain QoS. Instead of this, there is need that owner/administrator/management of the building should own the responsibility to provide good mobile network quality inside its building. They may get necessary work done and manage it via any Infrastructure Provider on L1 based model with desired QoS and time to time upgradation or expansions as per the requirements. Though, capital and operational cost discovered via L1 process may be shared among stakeholders.

5 Assessment on Airport Express Line and actions required to improve quality

5.1 Description of Route of Airport Express Line

Airport express line was developed and initially operated by M/s Reliance Infrastructure and it was opened on 23rd of February 2011[12]. Airport Express Line also known as orange line is one of the major transport connectivity for persons travelling from Delhi city area to T3

[12] https://en.wikipedia.org/wiki/Delhi_Airport_Metro_Express

terminal. It is also used by persons travelling to T1 and T2 Terminal areas. T2 terminal is walking distance away from T3, while to travel to T1 terminal bus transport connectivity is available from Aerocity station. Total length of airport express line is 22.7 Kms[13], out of which 15.7 kms is underground and 7 kms from Buddha Jayanti park to Mahipal pur is elevated. Its speed typically goes up to 80 kms per hour and it takes around 19 minutes from New Delhi Station to T3 terminal. Typical time spent by the user in the journey from New Delhi station to T3 terminal may go up to 30-35 minutes if waiting time for arrival of train and buying tickets is also included.

5.2 Current Set up of Radio Networks at Airport Express Line

Mobile users travelling via Airport Express line are served via leaky cable solutions deployed in tunnel areas and via IBS in station areas which are located underground. In elevated part of airport express line, users are served by outdoor radio network sites. To provide mobile services, M/s Reliance Infrastructure assigned RCOM (Reliance Communications), mobile network operator, to deploy and manage Leaky cable solutions in the tunnel area of the line and IBS at stations. RCOM was also responsible to provide connectivity to other operators for radiating their signals. In July 2013, DMRC took over the operations of Airport Express line. Leaky cable and IBS systems are now being operated and maintained by DMRC themselves while space required by mobile network operators to install equipment for connectivity is rented out to them by DMRC at a particular rate determined by it on the basis of earlier rates. Maintenance of the leaky cable and in-building solutions primarily lies with the DMRC.

[13] https://www.newdelhiairport.in/from-ndls-to-igi-airport-in-20-minutes.aspx

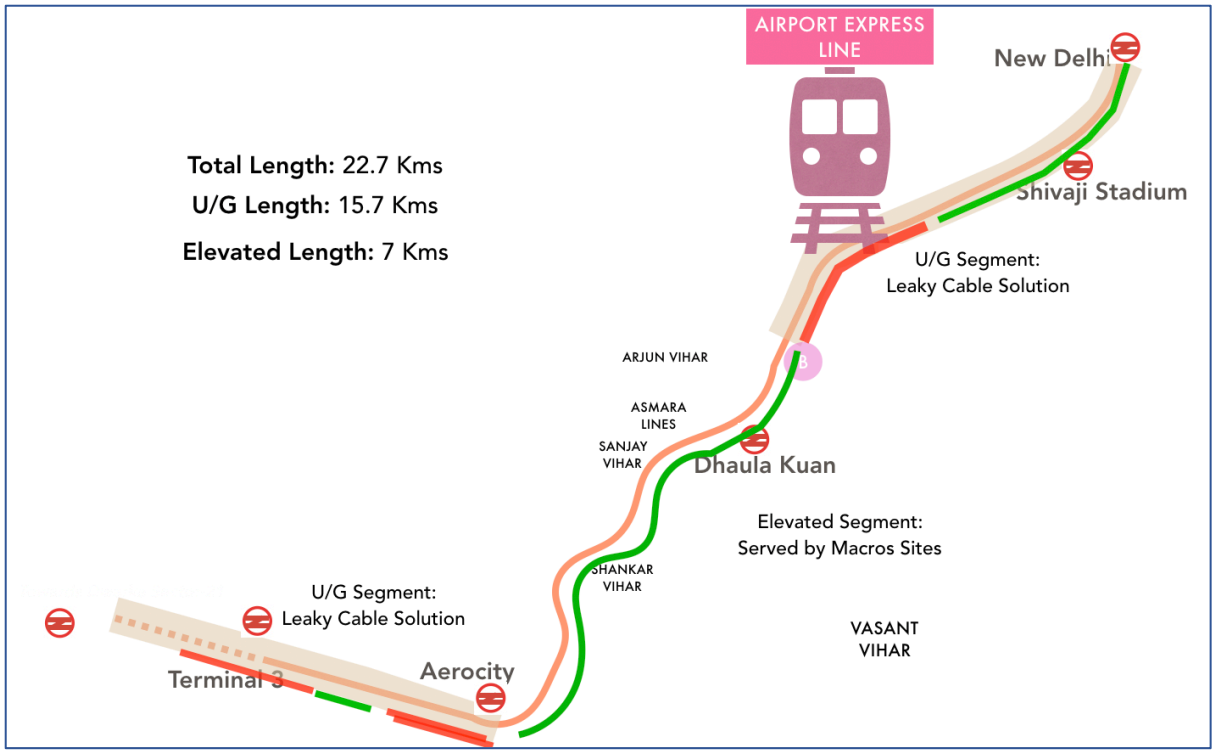

Figure 6: Leaky Cable and Outdoor Sites coverage on Airport Express Line

5.3 Issues in working of Indoor Solutions provided at Airport Express Line

It is observed that sections of leaky cable in the tunnel area is faulty and leads to no coverage area for all operators. Established calls or data sessions made before entering into this section are bound to drop for users of any of the network. DMRC intimated that they have initiated the process of an Infrastructure Provider to overhaul the current solution and would be required to meet stringent conditions for network coverage inside the tunnel and on underground metro stations. However, as far as selection process is concerned it seems to suffer with similar problems as of H1 model (highest bidder) observed in the case of T3 terminal building solutions. Though, DMRC indicated to put conditions on Infrastructure Provider to mandatorily give connectivity to all mobile network operators. This would solve "discriminatory" part of the problem but this might not solve the problem of "fair price" as exclusive rights are available with one provider. It may also not solve the problem of maintaining QoS to desired standards until and unless same are not defined in details specifically for this purpose and have legal requirements to comply with it. Problem of upgrading and expanding the deployed system in timely manner is also be similar to the one observed in case of T3 terminal building. This is also associated with the problem of "fair price" to be charged from participants to the system against the incremental cost incurred by the Infrastructure Provider.

Another problem of mobile network quality in case of combination of tunnel and elevated part is that there should be antennas installed very close to the entry and exit points of tunnel.

Such antennas should have radiated coverage area which partly goes into tunnel area and partly covers elevated part. This is essential requirement for smooth handover of calls or data sessions while passengers travelling in the Airport Express Line cross these points and change serving network from leaky cable network to the outdoor network or vice versa. If the mobile network operators do not have antennas on strategically appropriate locations then all established calls or data sessions are bound to drop. Even users who are attempting to make new calls in this section of line also observe poor quality of network.

5.4 Issues in Elevated Section of Airport Express Line

Elevated section of the line is more likely to get same quality as observed by the other users in neighbourhood area of line as both are being served by same outdoor network. Movement of trains in and out of tunnel creates spikes of traffic on periodic intervals depending upon frequency of trains and number of users travelling inside it. Outdoor sites serving elevated portion of the line observe this traffic spike movement across multiple sites. With average speed of train of 80 kmph, more than 500 meter distance may be covered by the user in a very short time span of about 30 seconds which may lead to multiple handovers. Radio technologies are designed and developed to support much higher speeds but there may be issues related to spare capacity available at that moment in the sites to which call is to be handed over. As outdoor sites are serving to other users in the neighbourhood area, instantaneous peak demand from users travelling in train combined with instantaneous peak demand of other users in neighbourhood of line will sometimes cause capacity crunch and will lead to handover failure. Such handover failures will impact either users travelling in airport express line or other users served by same radio network sites.

5.5 Adoption of latest technological solutions to improve quality

Now-a-days, new solutions have emerged to provide coverage inside tunnel areas such as Remote Radio Frequency (RF) Heads (RRH), Small cells etc. and these solutions are much better than leaky cable solutions in terms of upgrading solutions to support new radio access technologies, power loss in transmissions, smarter ways to handle traffic, efficient utilization of computing power etc. There is need to evolve the system to deploy latest technology solutions in the tunnel areas and at metro stations.

5.6 Need for DMRC to collaborate with TSPs in their benefit

DMRC is using TETRA technology based solutions for their own communications and have separate infrastructure to deploy radio networks for this purpose. LTE technology has evolved to provide all features which are available in TETRA technology. Train operations in many countries such as France have started migrating their current TETRA networks to LTE based Critical Communication networks. In this case, common infrastructure could be used for networks for commercial communications and networks for critical communications though

spectrum band may be dedicated for their own purposes. This convergence at infrastructure and radio technology level may bring cost efficiency and synergy for operation and maintenance of the system. Recently TRAI has sent a recommendations on "Next Generation Public Protection and Disaster Relief (PPDR) Communication Networks" on 4th of June 2018 to Government of India.

6 Assessment on Approach Roads from Dhaula Kuan to Airport and actions required to improve quality

6.1 Description of Roads towards Delhi Airport and neighborhood area

From Dhaula Kuan, Delhi Airport can be reached via multiple road routes and preferred route may be dependent upon the particular terminal which is to be reached to. Routes to reach T3 or T2 terminals from Dhaula Kuan is about 12.5 Kms and goes either via Mehram Nagar or via Mahipalpur, both of which merges into Northern Access road. Initial section of both routes, from Dhaula Kuan up to turning point on NH-48 for going to Terminal 1, is also common.

Routes to reach Terminal 1 and Technical Area of Airport from Dhaula Kuan is about 9 kms long and goes via Mehram Nagar area or via Cantonment Area. Initial section of Meharam Nagar route matches with common route for T2/ T3. Cantonment route, usually via Parade Road and then taking Thimmaya Marg. However, there may be other combinations of routes available in neighborhood area.

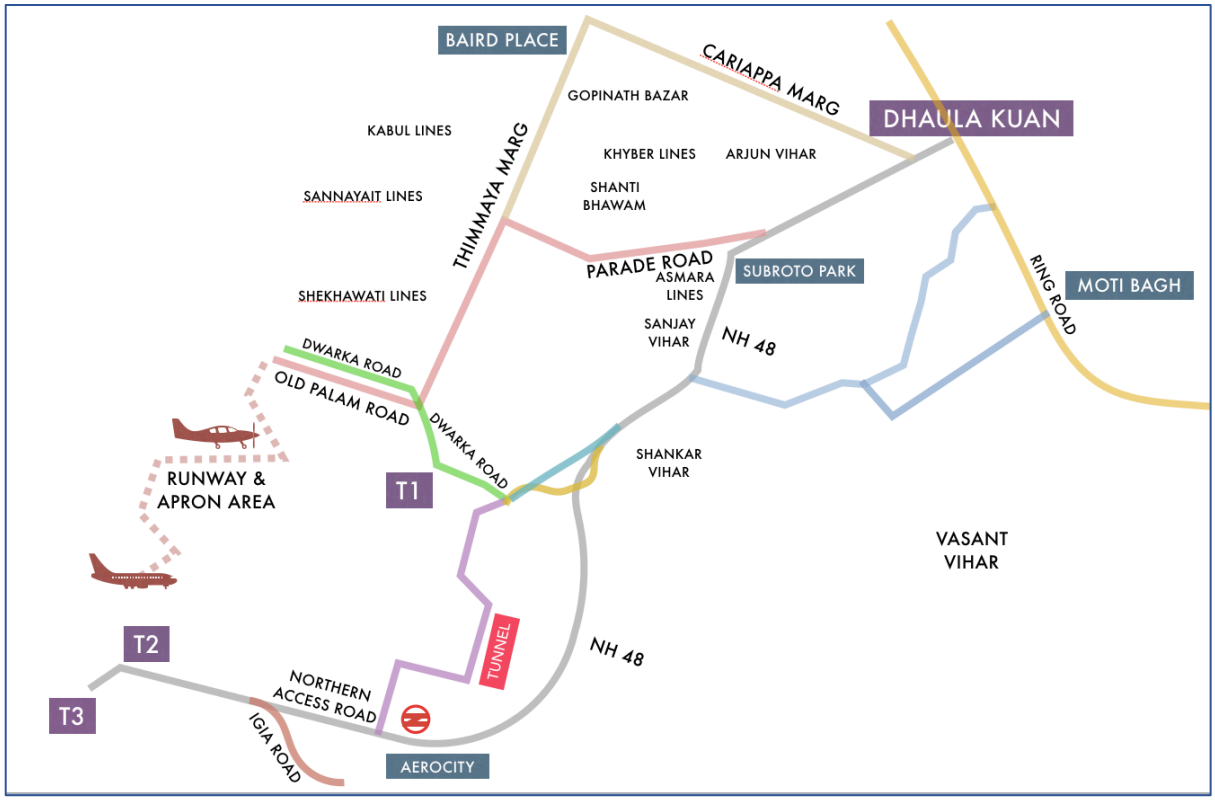

Figure 7: Various Roads between Dhaula Kuan and Delhi Airport

6.2 Need to analyze issue on sections of Area

For analyzing the issues related to mobile network quality on road routes, area may be divided in following parts:

- **Section-1A:** From Dhaula Kuan to Manekshaw Auditorium (the cut point for going on Parade Road) (*i.e. Road section along the Airport Express line from Metro Pillar #80 to Metro Pillar #140*)
- **Section-1B:** Manekshaw Auditorium to Intersection Point of Thimmayya Marg and Dwarka Road (*via Parade Road and then Thimmayya Marg*)
- **Section-1C:** Old Palam Road
- **Section-1D:** Ulan Batar or Terminal 1 Departure Road
- **Section-1E:** Ulan Batar or Termina 1 Arrival Road
- **Section-2A:** From Manekshaw Auditorium to the Turn Point on NH-48 for going to Dwarka Road/ Terminal-1 (*i.e. Road section along the Airport Express line from Metro Pillar #157 to Metro Pillar #240*)
- **Section-2B:** Section of NH-48 Road along Mahipalpur Extension, Mahipalpur and Rangpuri Nallapar
- **Section-2C:** IGIA Road Small Section between Mahipalpur and Intersection Point of Norther Access Road-IGIA Road
- **Section-3A:** From Dwarka Road Turn point on NH-48 to Intersection Point of Dwarka Road-Northern Access Road-Ulan Batar Road
- **Section-3B:** Intersection Point of Dwarka-Road-Northern Access Road-Ulan Batar Road to Intersection Point of Northern Access Road-Indira Gandhi International Airport Road (IGIA Road)
- **Section-3C:** Intersection Point of Norther Access Road-IGIA Road to Terminal 3/ Terminal 2

The above sections may be grouped into four areas namely Subroto Park area, Mahipalpur area, Cantonment area and GMR/DIAL area. Observations about network quality in these four areas is detailed in following paragraphs.

6.3 Subroto Park Area

6.3.1 Current deployment of radio networks in the area

Section-1A and Section-2A may be termed as Subroto Park area, which is a section of NH-48 and surrounded by area which is under control of Ministry of Defence (MoD). There is habited private colony and buildings available in a very small part of this section such as Jharera village and Sanjay vihar. In addition to this, Airport Express line, elevated on pillars, is also going along the road in this part of area. Permissions to install towers in area controlled by MoD is very difficult and many of the TSPs are utilizing pillars of elevated infrastructure to deploy

radio antennas. These pillars are located on every 25 meters and have height of about 10-12 meters. Antennas installed over these pillars have very small foot print as they are mounted at height of about 8 meters. It was also observed that, all pillars were not equipped with such antennas.

6.3.2 Alternative and better ways need to be explored

To install, antennas on pillars of elevated infrastructure is a nice way to provide coverage and capacity in such areas where users density on roads is very high. Every such antenna is equipped with electricity power supply and backhaul connectivity. However, deployment of such solutions seems to be limited to very small section as it seems to be a costlier option as it needs many antennas placed at very short intervals while there may be alternative ways available to serve same purpose in a cheaper way, for example, if there are opportunities to install antennas at height of 12-15 meters on poles located on the track of metro. It is needed that all TSPs in collaboration with officials from MoD and Airport Express Line to explore better options. This will help not only to avoid any gaps in coverage but also to solve similar problems in other areas.

6.4 Mahipalpur Area:

6.4.1 Current Set up of Radio Networks in the area

For discussion in this report, we may call section-2B which is a section of NH-48 along Shankar Vihar, Arjun Vihar, Mahipal pur Extension, Mahipalpur and Rangpuri Nallapar as “Mahipalpur area”. One side of this area is habited area while other side is controlled by GMR/DIAL and limited building structures are available. On the habitation side, there may be a number of choices available to mobile network for locations where they can install mobile towers. On the other side i.e. GMR/DIAL area, there are hotel buildings in Aerocity area and a Aerocity Metro station building on Airport Express line. Only metro station building is having a tower installed over its building, and no other building in neighboring area of this side of the road has tower installed either on its roof top or on its wall e.g., on hotel buildings in the Aerocity area. Other than roof top towers, only one CoW (Cell on Wheel) was present, on one location near Mehram Nagar, in this side of Mahipalpur area.

6.4.2 Challenges, peculiar to the area, in deployment of radio networks

Significant part of the Mahipal Pur area, falls under the funnel zone of Delhi Airport and there are restrictions on the locations where towers can be installed by the mobile network operators. Other part of area also has restrictions on permitted maximum heights and requires clearance from appropriate authorities.

Traffic capacity of radio network in this area is supposed to serve travelers to and from Delhi Airport and as well as heavy mobile communication traffic of commuters between Gurugram and Delhi. In addition to this, mobile communication traffic of residents in the area, hotel guests and other travelers on expressway is also to be served. Traffic demand of elevated part of Airport Express line are also met by same radio network. Instances of sudden high variations in the density of users in the area, need to be met by requisite margins in the radio network capacity. Radio network capacity can be built by installing more radio network sites and preferably, they should be well distributed over the area. Restrictions on locations and heights of towers cause capacity deficit or coverage gaps in the area. This capacity deficit or coverage gap results into unsuccessful call attempts, call drops due to unsuccessful handovers and even may result into longer and more frequent instances of voice mute during conversation e.g. in case of VoLTE (Voice over LTE).

Figure 8: Antennas mounted on Metro Pillars

6.4.3 Need to adopt innovative solutions to improve QoS

Probable approach to solve the issue may be to identify innovative and alternative ways to install antennas in these type situations. For example, wall mounted antennas on hotel buildings or other commercial buildings may help in improvement of coverage and capacity of the network. During discussion with the mobile network operators, it was found that there is lot of resistance by hoteliers to accept their proposal to install wall mounted antennas on their buildings as these mountings affects aesthetics of their building and the landscape. In such situations, chances of acceptance of proposals to building owners/ managers to allow to install antennas on their walls and towers on their roof tops or in premise may be increased substantially if camouflage techniques are used to deploy antennas. Camouflaged antennas may be multiple times costlier than normal antennas. In India, at some places such antennas were deployed but there may be requirement to do more customized work in each case specific to aesthetically blend in that instant case. Cost may go further high, if volume of such

work does not increase and in market more experts and product choices do not become available at affordable prices.

Figure 9: Few Hotel Buildings in Aerocity Area, where installation of antennas may likely improve network quality

Deployment of Small Cells which have relatively lower form factor and may be suitable, in certain cases, for building capacity and bridging coverage gaps. Access to fibre, already laid and available to use, or permission to lay additional fiber can enable competitive backhaul market. Backhaul connectivity is very important in cases of a greater number of sites which are located in more distributed manner. It becomes more relevant when line-of-sight connectivity is not available.

6.4.4 Option for DoT to consider

Relaxation in limits of maximum EIRP (Power emissions), in certain scenarios, where it may not be of much concern for which maximum limits were set would be very helpful to improve coverage and capacity of the network.

6.5 Cantonment Area:

6.5.1 Description of Area

Section 1B and 1D, is termed as cantonment area and permissions to install mobile towers in this area is under the control of Ministry of Defense (MoD). Many building structures are available in this area and there seems to be no technical difficulty in illumination of area by radio networks as there is no challenge in terms of building structure clutter. Only difficulty is to get permissions to install towers from the appropriate authorities. At present, all towers are CoWs (Cell on Wheels), which are temporary infrastructure and can be asked to remove at any time. As discussed in case of T3 building, COWs are limited in maximum height from the ground. COWs equipment is not supporting infrastructure sharing to use same COWs by all the telecom service providers.

Recently, MoD has identified buildings, considering various requests made by the TSPs, where permissions may be granted to install towers. However, approach is to first select single Infrastructure Provider through a tendering process and on the basis of H1 (highest one) bidding as selection criterion. The successful bidder gets exclusive right for certain time period and it subsequently enters into commercial agreement with different TSPs. Problems of fair price, non-discriminatory behavior with TSPs and problems of timely expansion, upgradation and upkeep of the equipment to meet evolving requirements is same or similar to problems discussed earlier in T3 building section.

6.5.2 Significant role of other actors than TSPs in improvement of quality

Elegant solution to the problem is by owning the responsibilities of helping in providing good quality mobile network in area which is exclusively controlled by government agencies. They need to designate telecom strategy nodal point, who coordinates with both parties, TSP on onside and other relevant offices on government side. Office of strategy nodal point need to have mobile networks experts as part of their team, and it should help in finalizing best feasible solution for the area and get it implemented on L1 based model. Expenses against implementation of the solution need to be shared on contributory basis among the participants. Similar approach need to be developed for expansion, upgradation and maintenance of the deployed equipment. Representatives are required to meet on periodical basis, and they are also required to assess performance of the network on regular basis. They are also required to take necessary actions. Institutional mechanism to take decision and sharing the responsibility to deploy solutions in cost effective and timely manner will substantially improve quality of services in the area.

6.6 GMR/ DIAL Area

6.6.1 Description of Area

GMR/DIAL controls the permissions in area leased out by AAI to it for 30 years. Area may include entire Delhi Airport area including landscape and roads upto Mahipalpur. Other than runway, apron and terminal buildings, this area includes open area, Udaan Bhawan, Multi-level Car parking, aerocity hotel buildings, New Custom House, BCAS office, residential area for selective staff etc. Permissions in this area to install towers, lay fibres etc. is granted by GMR/ DIAL.

6.6.2 Challenges, peculiar to area in deployment of radio networks

While granting permissions, various restrictions as per Gazette notifications of GSR 751[14] for fixed wireless stations may be applicable. Type of restrictions may differ in approach area or take off area of funnel zone and on road sides or on in case of requirement to install on

[14] http://www.civilaviation.gov.in/sites/default/files/Bilingual%20GSR_1.pdf

available building structures or in open areas. One more important concern raised by GMR during the discussions is to maintain aesthetics of the area and avoid disruptions because of involving multiple agencies in laying buried infrastructure such as laying fibre.

6.6.3 Current set up of deployed radio networks in the area

At present, permanent towers are installed on limited number of buildings such as Udaan Bhawan, Multi-level Car Parking (MLCP) Building, Centaur Hotel building.

Coverage is a main issue as most of the mobile communication traffic is from the users travelling in fast moving vehicles. As users in a particular radio cell are limited to the vehicles at that moment in that particular cell, traffic capacity is not an issue as such. There are pockets in this area such as pickup and drop off areas, where users might spend more time in a cell being relatively static, and high traffic demand because of a greater number of users being in that particular area have already been discussed earlier in T3 terminal section. To serve this traffic number of CoWs are deployed in addition to the permanent towers.

To cover entire area with good quality of network signal, permanent towers on limited number of buildings are not good enough. TSPs, with permissions from GMR/ DIAL, have deployed number of CoWs along the roads or in open area. Even these CoWs are not sufficient to cover every part of the area through which users pass through. This gap in coverage or patches of bad network signals, though small in size, results either into call drop or into poor call quality or slower data throughputs.

6.7 Impact of poor-quality patches on the user

There are certain identified patches where almost it is sure that user would pass through bad network quality phase and without deployment of additional towers/ antennas, these patches cannot be removed. One of such patches is encountered when passing though tunnel in Section-3A. Almost all users passing through this area when in conversation are most likely to experience drop of call. To solve this, antennas are to be installed on both the ends of tunnel. While one CoW has been deployed on one end of it, near Mehram Nagar, but permissions have not been granted to install, even a CoW, on the other end of the tunnel. Similarly, turning part of the Northern Access Road in Section-3A, especially near hotel building areas, also observes poor network quality patches. It also requires installation of antennas in open area or on walls of hotel buildings. Challenges in installations of antennas on hotel buildings have already been discussed in Mahipalpur area section.

6.8 Options to improve quality in the area

To improve coverage and quality of mobile network in this area, one of the options is to establish institutional mechanism as deliberated in Cantonment area section. Similarly, GMR/ DIAL need to share responsibilities to enable radio network infrastructure in the area on L1 based cost sharing model rather than considering it as a revenue maximization opportunity.

GMR/DIAL should not deny permissions to TSPs keen to lay their buried infrastructure which they feel is more cost effective than renting out from GMR/DIAL. For providing good quality of mobile network experience, objective should be to offer backhaul network also at a fair and reasonable cost sharing based mechanism among all stakeholders.

GMR/DIAL being single agency to grant permission to install tower and provide access to infrastructure at a price point determined by them and there is no way to determine competitive market price. For GMR/DIAL, currently there is no obligation to provide necessary support for providing mobile network infrastructure in timely manner and at a reasonable price. There is need to make it obligatory on agencies like GMR/DIAL to share this responsibility without which mobile network quality cannot be improved by TSPs on their own.

7 Assessment of services for users belonging to different service providers

In Delhi service area, M/s Airtel and M/s Vodafone-Idea Limited have 2G (GSM), 3G (WCDMA) and 4G (LTE) networks while M/s Reliance JIO (RJIO) has only 4G (LTE) networks. MTNL has only 2G and 3G networks and no LTE networks. In the Delhi Airport, deployment of Base stations in terms of numbers of base stations and their locations is not same for all TSPs. MTNL has very few base stations in comparison of others. Deployment of CoWs (Cell on Wheels) is also specific to TSPs except in few cases, where CoWs of almost all TSPs is located at same location such as in front of T3 terminal building.

In case of In Building solutions (IBS) terminal, there are variations in capabilities and support of IBS system specific to a TSP, for example, RJIO has LTE networks in multiple bands while T3 IBS supports LTE in only one spectrum band 850 MHz.

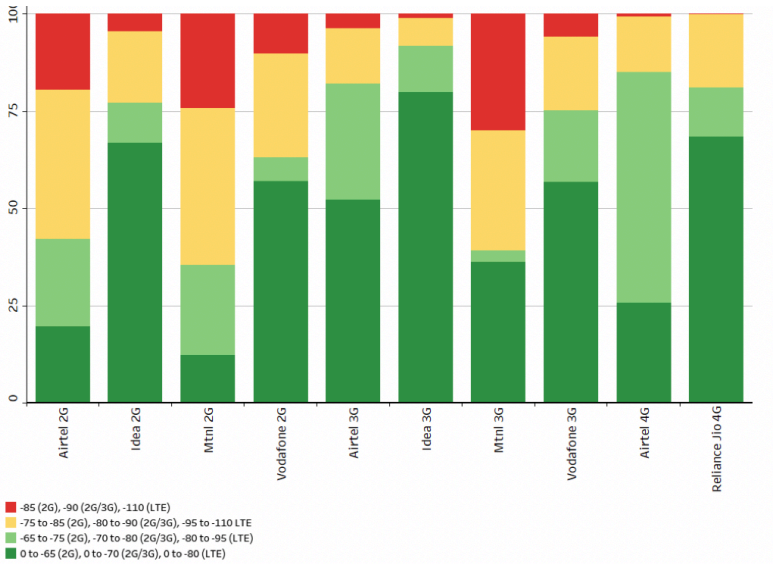

Figure 10: Network Signal Strength (Samples in percentage)

During testing, it was observed that all service providers except MTNL had Drop Call Rate (DCR) within 2% benchmark. It may be noted that DCR benchmark of 2% is for entire License Service Area (LSA) and not for specific pocket of the city. In case of MTNL higher DCR seems to be due to very few outdoor sites in the area in comparison to other TSPs. Statistics of Network signal strength observed in the area for various TSPs is shown in the chart. Coverage along the drive test road routes for various TSPs is shown in following diagrams where poor coverage signal patches are shown in red.

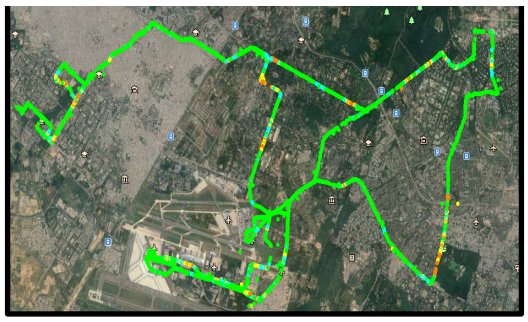

Figure 11: Reliance JIO 4G Coverage

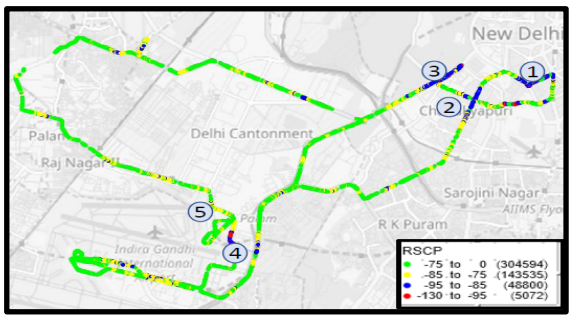

Figure 12: Vodafone 3G Coverage

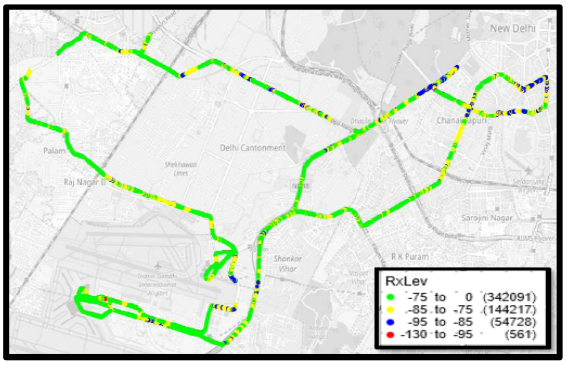

Figure 13: Vodafone 2G Coverage

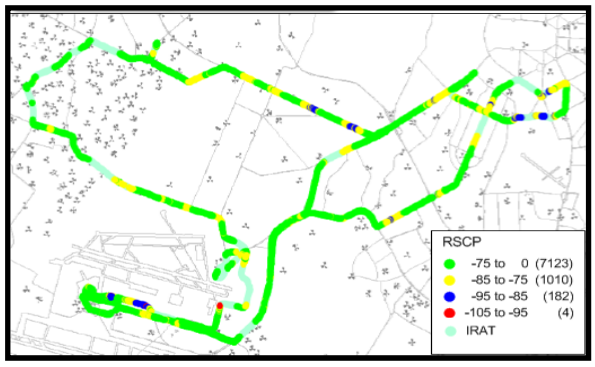

Figure 14: Idea 3G Coverage

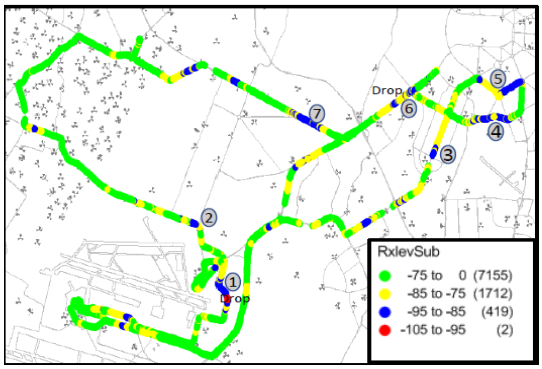

Figure 15: Idea 2G Coverage

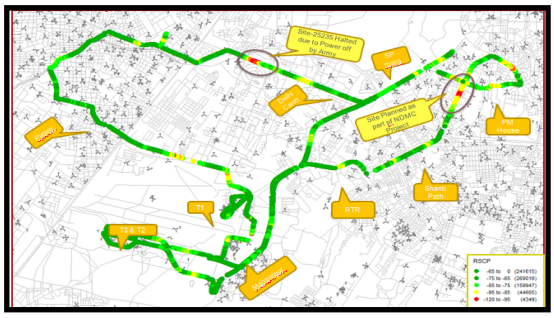

Figure 16: Airtel 3G Coverage

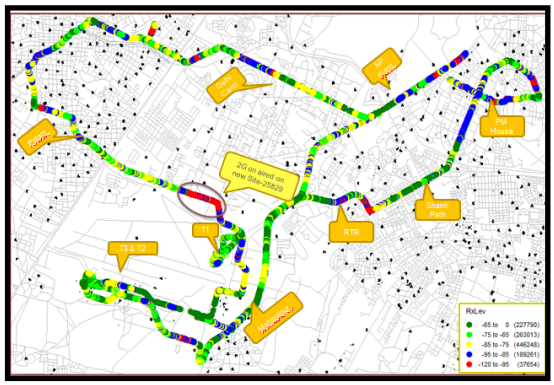

Figure 17: Airtel 2G Coverage

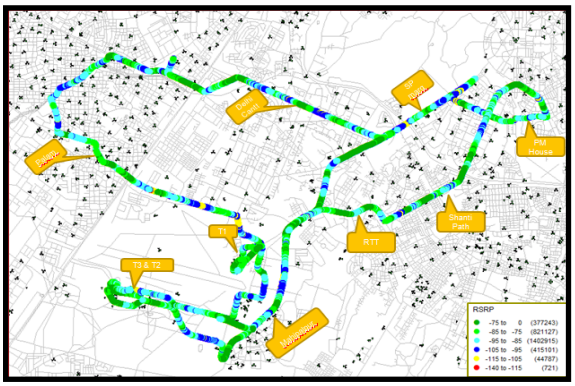

Figure 18: Airtel 4G Coverage

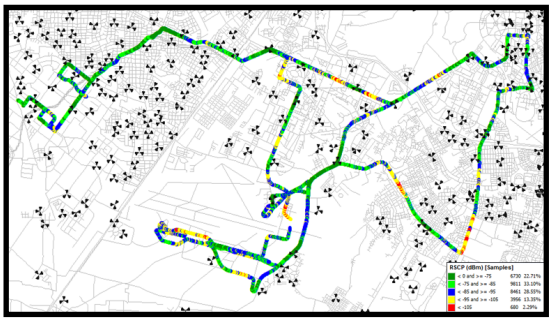

Figure 19: MTNL 3G Coverage

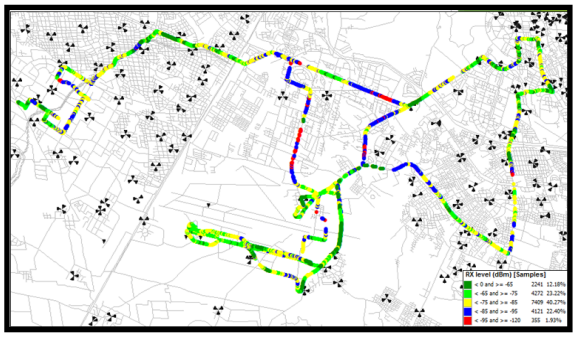

Figure 20: MTNL 2G Coverage

8 Summary of issues and actions required to improve quality

8.1 Problems observed

In Delhi Airport area including roads between Dhaula Kuan and Airport, there are different kinds of issues related to poor network and degree of extent of problem varies in different pockets and scenarios. Issues are related to network coverage i.e. availability of network, network capacity i.e. call setup success rate or data throughputs, and also network quality during conversation. Deficit in capacity is one of most important reasons causing poor quality during conversation or more frequent instances of voice muting. Experience of quality is different on roads, in Airport Express line, in terminal building areas and runway/ apron areas.

In Runway and Apron area, main issue is poor signal strength and in case of terminal building area, main issue is sufficient capacity of radio network. While in case of Airport Express line, patches with no coverage is a big issue and in case of roads, mix of all kinds of problems is a mix of coverage gaps, poor signal strengths and capacity crunch. Though these patches are limited in very small zones and capacity crunch is also limited to some selective time slots in a day. However, extent of poor experience to a user is dependent upon time spent by him in bad patch area and time slot during which one has passed through that area.

8.2 Issues due to infrastructure deficit

Key reason of coverage gaps and network capacity in outdoor areas is due to radio network infrastructure deficit and in indoor areas, it is due to In-Building Solutions (IBS) not supporting all radio access technologies deployed in outdoors and also not supporting all spectrum bands. Deficit in infrastructure can be judged from demand side peak requirements and supply side in terms of network capacity and spanning the network coverage in the area.

Demand side is sometimes very high in certain situations such as significant increase in user density in a particular pocket because of high density of vehicles on the roads (Airport traffic

plus commuters to and from Gurugram traffic plus commuters to and from Dwarka area traffic) combined with users in a passing by airport metro train.

Deficit in terms of coverage gaps or poor network signal strength is due to serving users from far located sites and also due to absence of sites at critical positions. To improve situation TSPs need to install more sites at appropriate locations to fill the gap. Enhancement of network capacity requires deployment of more radio network sites. To enhance capacity other options, need to be explored such as adding more layers in the radio network, radiating more power and using more efficient technology solutions.

8.3 Challenges for TSPs to solve the problem on their own

To bridge this deficit, primarily responsibility of maintaining good quality of service lies with the TSPs. However, in this specific situation, there are number of areas where TSPs are not in a position to solve the problems on their own as they are dependent upon number of factors which are authoritatively controlled by other actors and solely not determinable by competitive market forces. For examples, installing towers in GMR/DIAL areas, Cantonment areas and Hotel or building owners. Due to civil aviation area, there are lots of constraints on locations and maximum height which is allowed to TSPs to install towers.

Densification of radio sites or to cover area by emitting higher powers in certain specific situations is not under control of TSPs alone and need to be supported by authorities controlling the area and responsible to grant permissions. Such authorities express support but ways and mechanisms to granting permissions are not institutionalized and timelines to conclude the processes are not defined. Even mechanism to select infrastructure provider and give exclusive rights to them to operate leads to unfair, unreasonable commercial practices as these authorities are following H1 model to assign rights to a particular Infrastructure Provider (IP) resulting into a commercial model not appropriate for providing good mobile network quality.

Infrastructure Providers selected to install, operate and maintain infrastructure are not made responsible SLA to meet certain KPIs of mobile radio network performance on daily basis as required to be met by TSPs. Moreover, there is no framework and responsibility for these infrastructure providers under which they are supposed to work to maintain, upgrade and expand the network deployed by them to meet time to time requirements.

8.4 Actions to be taken on part of TSPs to improve the situation

TSPs are also required to take appropriate initiatives on their part to address the concerns of authorities controlling the area such as maintaining aesthetics of building and landscape while deploying their infrastructures. For example, techniques and solutions which camouflage antennas and infrastructure and aesthetically blend with the building infrastructure on which it is being installed. This will bring acceptance among authorities to agree for installing more

towers in the area where concerns is related to aesthetics. Deployment of antennas with smaller form factors suitable for a particular scenario would also be helpful. Innovative solutions more fit for special situations like runway and apron areas need to be explored by TSPs.

To maintain performance of mobile network in these areas, TSPs need to conduct testing on regular basis and at least twice a year in areas such as terminal buildings, runway and apron areas. They are also required to map test results onto floor layouts in case of terminal buildings. To address the deficiencies observed after analysis of test results, TSPs are required to take up the matter with Infrastructure Provider and concerned authorities for necessary actions which are required to be taken up to make changes or deploy additional radio network infrastructure.

TSPs are also required to include certain clauses as part of their commercial agreements with the infrastructure providers to maintain performance of the network at a level which is required to maintain good quality experience of the users. Necessary terms and conditions for upgrading and expanding the network is also be required to be included as part of the agreement.

8.5 Obligations which need to be part of Authorities controlling the area

There is a pressing need for having obligations on part of authorities controlling the area and buildings, such as GMR/DIAL, DMRC, Ministry of Defense (MoD) etc. who are controlling the area and granting the permissions to install towers, to own the responsibilities to solve the problem of the quality of mobile networks in their areas and extend the necessary support to TSPs to take remedial measures. These authorities are required to change the model of selecting infrastructure provider from H1 model to L1 model in order to make infrastructure support available to the TSPs at a fair and reasonable price. GMR/DIAL should bring in transparency in the procedure of granting permissions and charging the price by publishing the rates and methods to discover rates in public domain. Pricing should be cost based rather than maximizing the profit in a monopolistic situation. Authorities selecting Infrastructure provider to provide infrastructures to TSPs should also be assigned the responsibilities to such selected entity to timely upgrade, expand and maintain the radio network.

If these authorities designate an officer for the purpose of telecom strategy and finding a best feasible solution in the area under given constraints and alternative ways to provide good mobile network quality then it would be very useful in long run, not only from the perspective of users passing through this area but also other users who are residents of the area or it is their workplace.

8.6 Actions on part of DoT which would help in improving the quality

DoT need to examine various structural issues in solving the problem which are highlighted

earlier. DoT is also requested to give due considerations to TRAI's recommendations on "In Building Solutions" and accept it at the earliest.

Abbreviations and Acronyms

AAI	Airport Authority of India		**LSA**	License Service Area
ATC	Air Traffic Controller		**LTE**	Long Term Evolution *(4th Generation Mobile Technology is based on LTE)*
CDF	Common Distribution Facility		**MLCP**	Multi-Level Car Parking
CoW	Cell on Wheel *(Portable Base Station)*		**MoD**	Ministry of Defense
DCR	Drop Call Rate		**MTNL**	Mahanagar Telephone Nigam Limited
DIAL	Delhi International Airport Limited		**NH 48**	National Highway 48
DMRC	Delhi Metro Rail Corporation *(Also operating Airport Express Line)*		**OTT**	Over The Top *(Applications)*
DoT	Department of Telecom		**PPDR**	Public Protection and Disaster Recovery
GMR	GMR Group *(Infrastructural Company)*		**RRH**	Remote RF (Radio Frequency) Head
GSM	GSM based mobile network *(2nd Generation Mobile Technology)*		**SLA**	Service Level Agreement
GSR	Gazette Notification issued by Ministry of Civil Aviation *(30th September 2015)*		**T1**	Terminal 1 of Delhi Airport *(Domestic)*
HSPA	High Speed Packet Access *(Evolution of 3rd Generation Mobile Technology)*		**T2**	Terminal 2 of Delhi Airport *(Domestic)*
H1	Highest revenue bidder in selection process		**T3**	Terminal 3 of Delhi Airport *(International and Domestic)*
IBS	In Building Solution		**TETRA**	Terrestrial Trunked Radio *(Private Mobile Radio System)*
IGIA	Indira Gandhi International Airport		**TRAI**	Telecom Regulatory Authority of India
IP	Infrastructure Provider		**TSP**	Telecom Service Provider
KPI	Key Performance Indicator		**VoLTE**	Voice over LTE
L1	Lowest cost bidder to implement solution		**WCDMA**	Wideband Code Division Multiple Access *(3rd Generation Mobile Technology)*