ROLE & IMPORTANCE OF NEXT GENERATION WI-FI TECHNOLOGIES IN ACCELERATION OF DIGITAL TRANSFORMATION

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The Internet is the invention of our age, having an effect on every aspect of human life. From an economic standpoint, it has been broadly estimated that a 10% increase in broadband penetration in a country could potentially lead to an over 1% increase in GDP. Demand for data is exponentially increasing, supported by an affordable device ecosystem, availability of a variety of quality content, OTT services, e-education, healthcare, etc. and many new use cases. Covid-19 has fueled this demand further multifold. Global communication networks, largely based on wireless communication platforms, provide ubiquitous connectivity, interactive communication in chosen time, transcending traditional boundaries. Mobile and Wi-Fi (Wireless Fidelity) have been the two key technologies in the wireless space. With the creation of IEEE 802.11 standard committee in 1997, and release of the first standard in 1999, Wi-Fi as a technology will soon complete a glorious 22 years of existence and innovations. The innovations brought in the Wi-Fi standards, products and solutions at regular intervals, to address the connectivity needs, have made it one of the most used technologies globally.

Wi-Fi brings many advantages in terms of very low CAPEX and OPEX, very easy to deploy, easy to maintain, easy to operate, easy to use and coreless technology. It is also complemented by the device ecosystem where Wi-Fi radio is available in almost all smartphones, tablets, laptops and even desktops, by adding a small dongle. Telecom operators around the world are utilizing the Wi-Fi technology to offload data and call traffic to unlicensed bands, so that they can keep the Capex low and maintain the quality of service for more real time applications.

Wi-Fi technology is based on IEEE 802.11 standards and operates in unlicensed 2.4 GHz and 5 GHz spectrum bands. The Wi-Fi standardization and technology adoption activities are driven by multiple global organizations and these standards keep evolving in order to achieve better speed and support for multiple use cases. With ratification of latest 802.11ax standards, it also operates in 6 GHz band spectrum — referred to as Wi-Fi 6E — which is considered to be a game changing evolution to bring Wi-Fi at par with 5G cellular technology. In India, TSDSI (Telecommunications Standards Development Society, India), BIF (Broadband India Forum), ITU-APT Foundation of India and WPC (Wireless Planning Commission) have already taken up technical studies and broader industry consultations on use of the 6 GHz band in the country. Another band, in some cases part of it, that has been de-licensed in several countries is V band (57 to 71 GHz), in order to increase capacity.

Wi-Fi technology is contributing significantly to the global economy and its contribution is expected to grow to almost $5 trillion by 2025. The latest Wi-Fi trends include worldwide adoption of 6 GHz for Wi-Fi, use in the Industrial environment, Convergence with Cellular technology such as 4G and 5G, Motion sensing, Wi-Fi 6/6E deployments, Connected cars, etc. Innovative methods to deliver Wi-Fi through public hotspots like PM-WANI in India are emerging, where each element in the value chain is unbundled to spur innovation and promote entrepreneurship.
Many initiatives have been taken by the government to increase broadband penetration and promote Wi-Fi in the last mile. As per TRAI’s recent report, the total base of internet subscribers in the country increased from a total of 238.71 million in 2014 to 776.45 million in 2020, registering a CAGR of around 22%. The data usage per user per year in GB has increased from 3.24 GB in 2014 to a whopping 141.11 GB in 2020. At the same time, the data cost to subscribers per GB in rupees drastically fell from Rs. 269 in 2014 to Rs. 11 in 2020. While India has made significant development in internet penetration over the years, there is still a large scope for growth in speeds and connecting the unconnected or poorly connected. We have only about 0.4 million hotspots against a requirement of 8-10 million hotspots to be on par with the global average. One of the ways to connect the unconnected is through public Wi-Fi hotspots.

As per Cisco’s annual internet (2018 to 2023) report, Wi-Fi speeds from mobile devices will triple by 2023. Globally, the average Wi-Fi speeds will grow from 30.3 Mbps in 2018 to 92 Mbps by 2023. Wi-Fi hotspots will grow four-fold from 2018 to 2023. Globally, there will be nearly 628 million public Wi-Fi hotspots by 2023, up from 169 million hotspots in 2018. Wi-Fi 6 hotspots will grow 13-fold from 2020 to 2023 and will be 11 percent of all public Wi-Fi hotspots by 2023. By 2023, APAC will have 49 percent of all networked devices mobile-connected and 51 percent will be wired or connected over Wi-Fi. By 2023, APAC’s average Wi-Fi speeds from mobile devices will reach 116 Mbps, which represents 3.4-fold growth from 2018 (34.5 Mbps). Therefore, it is clear that Wi-Fi hotspots will play a major role in providing broadband services in the country.

To increase the proliferation of broadband in the country through public Wi-Fi hotspots, a unique ‘unbundled and distributed model’ for delivery of broadband services through public Wi-Fi Networks has been rolled out in the country under the framework of the Prime Minister’s Wi-Fi Access Network Interface (PM-WANI) on 9th December 2020. This framework takes forward the goal of the National Digital Communications Policy, (NDCP) 2018 of creating a robust digital communications infrastructure; deployment of 10 million public Wi-Fi hotspots and broadband for all by 2022. The Wi-Fi Access Network Interface (WANI) framework enables provision of Broadband through Public Wi-Fi Hotspot providers.
Further, the Government has resolved to take broadband to each of the 6 lakh plus villages in the country. Our Hon’ble Prime Minister has announced that all 6 lakh plus villages will be connected by fiber in 1000 days. While the planning and execution of the work is in progress, pilots done by C-DOT have shown that Wi-Fi can be used to extend connectivity from Gram Panchayats to villages. Use of Wi-Fi technology to establish point to point and multipoint microwave links in unlicensed 5 GHz band is one of the alternate and affordable technologies to extend the BhartNet fibre pipes from Gram Panchayats to nearby villages. The bandwidth dropped in the village either through fiber or Wi-Fi can be further distributed using Wi-Fi hotspots. These hotspots can be made PM-WANI compliant to provide various services in the village. Deployment of such infrastructure is already underway in the country by C-DOT on a pilot basis.

Given the benefit of the PM-WANI framework, there is ample opportunity to replicate this model in other countries by globalising these WANI standards. C-DOT is already driving the effort of developing a global standard based on the WANI framework in IEEE SA through the P2872 Working Group, also known as Standard for Interoperable and Secure Wireless Local Area Network (WLAN) Infrastructure and Architecture (ISAWANI).

The PM-WANI scheme has taken off well. More than 50 PDOAs and 27 APP Providers are already registered in the ecosystem and around 50 thousand Access Point Radios are deployed in a very short span of time. This number is expected to grow exponentially in the near future. However, to further accelerate the rollout of the scheme, certain issues need to be resolved. As this is a new and innovative scheme, efforts are needed to create wider awareness about the novel scheme, its technical design, utility of Public Wi-Fi services and associated benefits. For easy availability of WANI compliant devices in the market, vendors can be encouraged to seek TEC certification. TEC certification for WANI compliance can facilitate off-the-shelf equipment for faster deployment. However, there should not be mandatory requirement for TEC certification. There is a possibility of vertical squeeze as TSPs, who are wholesale providers of bandwidth to PDOs, are also retail players themselves. Therefore, there is a need for fair, reasonable and non-discriminatory pricing rules for bandwidth. A regulation prescribing ceiling rate with guaranteed QoS can be considered by TRAI to ensure that ISPs/TSPs do not exercise discriminatory practices in allocating bandwidth and pricing for PDOAs/PDOs under PM-WANI.

Several thousand entrepreneurs are expected to take the scheme forward, and many small entrepreneurs will find it difficult to scale up the business due to lack of access to capital at reasonable terms. Government could facilitate schemes for micro-financing with tie up with banks or partial funding from USOF for small entrepreneurs to invest in PDO/PDOA business under PM-WANI. Roaming between different PDOA locations is one of the key requirements so that the customer is not restricted to a particular location or area served by a PDOA, from which it has purchased the service. Suitable modifications can be made in the WANI framework.
to enable roaming among PDOAs. Telecom Service Providers (TSPs) in India have far less
licensed spectrum for mobile services than those in other countries. Furthermore, the quantum
of unlicensed spectrum in India is far lower in comparison to several other countries. India has
around 689 MHz (2.4 GHz & 5 GHz band) of spectrum available for unlicensed use, spread
across various spectrum bands compared to around 15000 MHz (2.4 GHz, 5 GHz, 6 GHz & 60
GHz band) in countries like the USA, China, Japan, UK, etc. Telecom operators are also utilizing
the Wi-Fi technology to offload their subscriber activity to unlicensed bands so that they can
keep the Capex low and maintain the quality of service for more real time applications. Existing
2.4 GHz band has already been crowded, and the 5 GHz band is likely to be crowded soon.
To support evolving use cases and data demand, it is very important to explore opening up
additional bands for unlicensed usage. To increase the capacity, Wi-Fi now has standards in the
6 GHz (Wi-Fi 6E) and 60 GHz band (a variant of Wi-Fi also called Wi-Gig). This allows for higher
bandwidth channels, greater number of channels and higher speeds. Many countries have
opened up additional spectrum in unlicensed bands to meet increasing demand. The United
States Federal Communications Commission (FCC) approved opening up the 6 GHz frequency
band for unlicensed use by Wi-Fi 6 technology in April 2020, a decision many called historic.
Similarly, countries like the UK, South Korea, Chile, Brazil, Canada, Morocco, Peru, Saudi Arabia,
UAE and European Union have opened up the 6 GHz band as an unlicensed band. The ability to
leverage the 6 GHz band for unlicensed Wi-Fi operation — referred to as Wi-Fi 6E — will deliver
faster connectivity speeds and improved capacity. Similarly, a major part of V band (57 to
71 GHz) has been delicensed in about 70 countries of the world to increase capacity
and accelerate economic growth. There is a need to explore releasing these
bands in the country at the earliest, to unlock economic value from these
bands by providing broadband access through Wi-Fi using these bands.

Telecom products play an important role in the larger vision of
“Digital India”. While the production of electronic goods in the
country has increased from $29 billion in 2014-2015 to $70 billion
in 2018-2019, the trade deficit has also increased from $32 billion
to $48 billion in the same period. Given the huge market size of
India and availability of the right talent, various telecom products
including Wi-Fi products can be produced in India to meet local
demand and export to other countries. To promote indigenous
manufacturing, the Government has notified PMI (Preference to
Make in India) and recently PLI (Productivity Linked Incentives)
Policies. The PMI policy is to leverage the large domestic market
to nurture domestic companies, making available the market access
to the domestic companies and enabling them to scale up their
production, and also become competitive. PLI (Production Linked
Incentive Scheme), with the objective to boost domestic manufacturing,
investments and export in the telecom and networking products, has
been notified recently with an outlay of Rs. 12,195 Crores over a period
of 5 years. The scheme envisages to create global champions out of India
who have the potential to grow in size and scale using cutting edge technology,
and thereby penetrate the global value chains. However, issues related to easy access
to capital, improving associated infrastructure, quick product certification, removing trade
barriers, offsetting cost barriers, cross-checking local content in so-called ‘Made in India’
products, etc. are required to be addressed on a regular basis.

Constant interaction with stakeholders is necessary to identify roadblocks and make
suitable policy changes to fast track deployment of Wi-Fi technology and strengthen the
Wi-Fi ecosystem in the country. This will give impetus to the ‘Digital India’ Initiative of the
government, promote innovations in multiple sectors and spur economic growth.

On June 20th, we will be celebrating World Wi-Fi Day\(^1\), an initiative of Wireless Broadband
Alliance (WBA), in recognition of the fundamental role Wi-Fi plays in our day to day lives,
emphasizing the importance of connectivity for all, and showing our commitment to connect
the poorly connected and unconnected. Wi-Fi, as a complementary technology for broadband
access, is a major driver of growth envisaged in the ‘Digital India’ initiative. Therefore, it's
important that we further strengthen the ecosystem in the country for its fast proliferation for
connecting the unconnected and realizing economic benefits.
The Internet is the invention of our age, having an effect on every aspect of human life. From an economic standpoint, it has been broadly estimated that a 10% increase in broadband penetration in a country could potentially lead to an over 1% increase in GDP. Affordable data demand is exponentially increasing, supported by an affordable device ecosystem, availability of a variety of quality content, OTT services, e-education, healthcare, etc. and many new use cases. Covid-19 has fueled this demand further multifold. Global communication networks, largely based on wireless communication platforms, provide ubiquitous connectivity, interactive communication in chosen time, transcending traditional boundaries. Mobile and Wi-Fi have been the two key technologies in the wireless space. With the creation of IEEE 802.11 standard committee in 1997, and release of the first standard in 1999, Wi-Fi (Wireless Fidelity) as a technology will soon complete a glorious 22 years of existence and innovations. The innovations brought in the Wi-Fi standards, products and solutions at regular intervals to address the connectivity needs have made it one of the most used technologies globally.

Wi-Fi brings many advantages in terms of very low CAPEX and OPEX, very easy to deploy, easy to maintain, easy to operate, easy to use and coreless technology. It is also complemented by the device ecosystem where Wi-Fi radio is available in almost all smartphones, tablets, laptops and even desktops (by adding a very low cost small dongle). Telecom operators are utilizing the Wi-Fi technology to offload their subscriber activity to unlicensed bands so that they can keep the Capex low and maintain the quality of service for more real time applications.

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In 2021, the global economic value provided by Wi-Fi will reach $3.3 trillion USD and is expected to grow to almost $5 trillion by 2025. This growth represents a 150 percent increase from the 2018 value of $1.96 trillion to the projected value in 2025, underscoring Wi-Fi’s critical role in economies across the globe.

The recent report on “The Economic Value of Wi-Fi Spectrum for India” by Broadband India Forum (BIF) estimates Wi-Fi value to be almost Rs. 12.7 lakh crores and data rate per GB over Wi-Fi reducing to less than Rs. 23.

On June 20th, we will be celebrating World Wi-Fi Day in recognition of the fundamental role Wi-Fi plays in our day to day lives, emphasizing the importance of connectivity for all and showing our commitment to connect the poorly connected and unconnected. Wi-Fi, as a complementary technology for broadband access, is a major driver of growth envisaged in the Digital India initiative. Therefore, it’s important that we further strengthen the ecosystem in the country for its fast proliferation for connecting the unconnected and realizing economic benefits.
The Wi-Fi standardization and technology adoption activities are driven by multiple global organizations. Institute of Electrical and Electronics Engineers (IEEE) 802.11, Institute of Electrical and Electronics Engineers Standards Association (IEEE SA), Wi-Fi Alliance (WFA), Wireless Broadband Alliance (WBA), Telecom Infra Project (TIP), European Telecommunications Standards Institute (ETSI), 3GPP are major organizations leading this effort.

IEEE 802.11 is a standards working group (WG) which specifies the Wi-Fi standards that define a set of media access control (MAC) and physical layer (PHY) protocols for implementing wireless local area network (WLAN) computer communication. Over the last two decades, Wi-Fi standards have evolved to achieve speeds from 2 Mbps to multi gigabit, a 1000x increase in throughput. Starting from 802.11b, new protocols such as 802.11g, 802.11n, 802.11ac and 802.11ax (Wi-Fi 6/6E) have been introduced to achieve higher speed and improvement in other parameters. In addition to increasing peak data rates, evolving standards also improve spectral efficiency which characterizes how well the system uses the available spectrum. The new standards have evolved to support new multiplexing schemes such as OFDM and OFDMA and of higher order of modulation such as 64 QAM, 256 QAM and 1024 QAM to achieve higher data rates. Multi-user techniques such as multi-user MIMO (MU-MIMO) and orthogonal frequency division multiple access (OFDMA) have been introduced to improve network efficiency and network capacity. These new standards also support transmission of multiple streams to a single client or multiple clients simultaneously.

The standard and amendments as shown in image below provide the basis for wireless network products using the Wi-Fi brand:

Wi-Fi Operates in unlicensed bands 2.4 GHz, 5 GHz and now 6 GHz band is also supported in most recent 802.11ax standards - known as Wi-Fi 6/6E - defined by IEEE 802.11 WG. This is a very significant standard which brings Wi-Fi at par with cellular standards and meets technical requirements of 5G eMBB (Enhanced Mobile Broadband) use cases defined by ITU. This standard supports OFDMA (Orthogonal Frequency Division Multiple Access) modulation in both downlink and uplink, multi user (MU) MIMO in both uplink and downlink, Target Wake Time (TWT) for more battery life and support to IoT devices, operation in 2.4, 5 and 6 GHz band, etc., and can provide data rates up to 9.6 Gbps. This standard is already approved. Many OEM/ODMs have already started shipping Access points and client devices supporting Wi-Fi 6/6E globally.
IEEE 802.11 WG has already started the standardization work to define the next generation of Wi-Fi standards i.e., Wi-Fi 7 in IEEE 802.11 by Extremely High Throughput Task group. These enhancements will define the next generation of Wi-Fi. The standard is estimated to be completed by 2024. One of the main goals of Wi-Fi 7 is to increase the capacity and data rate beyond 9.6 Gbps of Wi-Fi 6. In Wi-Fi 7, the maximum data rate is 46 Gbps in 320 MHz channel and one 160 MHz channel in 5 GHz band with 4096 QAM and 16 spatial streams.

IEEE 802.11 working group is also creating multiple other standards for Wireless Local Area Network (WLAN) to support multiple other services such as broadcast services (IEEE 802.11bc), operation in unlicensed 60 GHz band (IEEE 802.11ad/ay), location services (IEEE 802.11az), Motion Sensing use case (IEEE 802.11bf), Light based communication (IEEE 802.11bb), Vehicular communication (IEEE 802.11bd), MAC Randomization (IEEE 802.11bh) and Data privacy in WLAN (IEEE 802.11bi).

The Institute of Electrical and Electronics Engineers Standards Association (IEEE SA) provides a neutral platform that unites communities for standards development and technological innovation and is independent of any government oversight. P2872 - Standard for Interoperable and Secure Wireless Local Area Network (WLAN) Infrastructure and Architecture (ISAWANI), P2061 (Frugal-5G), P1941.1 (Internet Grade of Services), etc. are under development at IEEE SA.

Wi-Fi Alliance drives global Wi-Fi adoption and evolution and its work includes the development of innovative technologies, requirements, and test programs that help ensure Wi-Fi provides users the interoperability, security, and reliability they have come to expect. Wi-Fi Alliance Certification or Wi-Fi CERTIFIED is an internationally recognized seal of approval for products indicating that they have met industry-agreed standards for interoperability, security, and a range of application specific protocols. Wi-Fi Alliance certification programs cover the categories such as Connectivity, Security, Access, Applications and Services, Optimization, RF Coexistence. Wi-Fi CERTIFIED 6, Wi-Fi CERTIFIED WPA3, Passpoint, etc. are globally recognized Wi-Fi product certifications. Wi-Fi Alliance also advocates the spectrum requirements for Wi-Fi and works with global regulators. It also publishes the statistics of projection of Wi-Fi device shipments worldwide and the economic value of Wi-Fi.

Wireless Broadband Alliance (WBA) undertakes programs and activities to address business and technical issues, as well as opportunities for member companies. WBA work areas include advocacy, industry guidelines, trials and certification. Its key programs include NextGen Wi-Fi, 5G, IoT, Testing & Interoperability, Roaming and Policy & Regulatory Affairs, with member-led Work Groups dedicated to resolving standards and technical issues to promote end-to-end services and accelerate business opportunities. Wireless Roaming Intermediary eXchange (WRIX) Framework and OpenRoaming are the major standards developed by WBA to bring seamless user experience to Wi-Fi users during roaming.
The Telecom Infra Project (TIP)\cite{15} is a global community of companies and organizations working together to accelerate the development and deployment of open, disaggregated, and standards-based technology solutions that deliver high quality connectivity. TIP is actively working in the Wi-Fi domain through Wi-Fi solution and Open Converged Wireless group. The Wi-Fi solution project group is focused on making End-to-End Wi-Fi connectivity solutions a success. OpenWiFi is the first project developed and contributed by the Open Converged Wireless community. OpenWiFi is a community-developed, disaggregated Wi-Fi software system, offered as free open-source software, that includes both a cloud controller SDK and an Enterprise-grade Access Point (AP) firmware, designed and validated to work seamlessly together.

The ETSI Industry Specification Group on Multi-Access Edge Computing, ISG MEC, has recently released ETSI MEC GS 028 to extend network information services to the world of Wi-Fi. Multi-access Edge Computing defines a standardized set of service APIs for applications at the edge of the network where the environment is characterized by low latency, proximity, and high bandwidth. These features are addressed through specific RESTful Application Programming Interfaces (APIs)\cite{16}.

3GPP specifies support of multiple access technologies and also the handover between these accesses. The idea was to bring convergence using a unique core network providing various IP-based services over multiple access technologies, including non-3GPP technologies to interconnect the UE and the EPC\cite{17}. Non-3GPP access such as WLAN or Wi-Fi is supported through interworking functions such as ePDG (Evolved Packet Data Gateway) for 4G core and Non-3GPP InterWorking Function (N3IWF) for 5G core in release 15 onwards. The integration of Wi-Fi to 4G/5G core will enable Mobile Data Offload (MDO) and Wi-Fi Calling functionality in the network. This leads to reduced use of licensed spectrum by offloading the communication to unlicensed bands, bringing down the Capex of the network significantly.
Covid-19 pandemic and its perilous effect in every aspect of human life made connectivity a basic human need. Day to day activities such as children’s education, healthcare for family, purchasing groceries, entertainment, infotainment, social networking, working from home, etc. all required connectivity. The changing usage scenario included more bandwidth intensive applications and real-time communications, requiring a network that delivers quality of service and good experience. Wi-Fi played a very important role in keeping people connected and supporting cellular infrastructure to meet the humongous needs. With evolving standards, Wi-Fi is being used not only at home environments or in enterprise setup, but also addressing the needs of multiple segments and creating new use cases. Latest trends include worldwide adoption of 6 GHz for Wi-Fi, use in the Industrial environment, Convergence with Cellular technology such as 4G and 5G, Motion sensing, Wi-Fi 6E deployments, Connected cars, etc.

The existing 2.4 GHz band was already crowded due to legacy devices and crowded deployments. The 5 GHz band, with around 605 MHz bandwidth, so far supported increasing data demand. However, going forward, with the need for newer applications, the 5 GHz will be crowded soon and won’t be able to support increasing data demand. Further, the use cases (including 5G use cases) that require deterministic behaviour of the network with very low latency and increased performance, are not suitable in the 5 GHz band. To support evolving use cases and data demand, it became important to open the 6 GHz band for unlicensed usage.

With IEEE 802.11ax or Wi-Fi 6E supporting the 6 GHz spectrum use for Wi-Fi technology, regulators across the regions have taken decisions in this subject matter to open up the 6 GHz band fully or partly depending on the geography, incumbent technology in operation, etc. FCC of the United States of America opened the complete 1200 MHz in 6 GHz band (5.925 to 7.125 MHz) in April 2020. Total 10 countries including South Korea, Saudi Arabia, Brazil, Canada, Chile, Costa Rica, Peru, Honduras and Guatemala have adopted the full 6 GHz band for unlicensed usage. The UK has opened the band partially. Twenty four more countries are either considering or have taken decisions to fully or partly open the same so far.

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[Image: World map showing countries with adopted 5925-6425 MHz and 5925-7125 MHz bands.]

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Role and Importance of Next Generation Wi-Fi Technologies in Acceleration of Digital Transformation
In India, TSDSI (Telecommunications Standards Development Society, India), BIF (Broadband India Forum), ITU-APT Foundation of India and WPC (Wireless Planning Commission) have already taken up technical studies and broader industry consultation on use of the 6 GHz band spectrum in the country.

The world has seen deployment of **Wi-Fi 6 devices** starting from 2019, with support made available in multiple mobile devices. Multiple OEM/ODM have launched Wi-Fi 6 Access points and today more than 2.2 billion Wi-Fi 6 devices are shipped globally. 6 GHz support in IEEE 802.11ax standard has led to Wi-Fi 6E products development and 338 million devices already shipped. In 2020, Wireless Broadband Alliance had conducted global trial deployments of Wi-Fi 6 across diverse markets. Each deployment addressed several challenges in vertical markets Industrial manufacturing, High density malls, single family multi dwelling buildings, Transportation and Education in Rural areas.

The global **Industrial IoT (IIoT)** market is expected to grow exponentially. Wireless connectivity is estimated to become an integral part of network deployment as part of Industry 4.0 and Connected Factory (CF) transformation. Wi-Fi is the most prevalent wireless technology to provide access to mobile workers in the Industrial environment, drive mobile automation and control devices and applications. Wi-Fi solutions were limited in manufacturing due to the challenge of meeting stringent latency and reliability requirements. Now the industry is able to leverage the new features such as improved performance, low latency and deterministic network behaviour possible with Wi-Fi 6/6E technology, to meet the performance requirements in challenging industrial environments including stringent requirements of latency in IIoT setup.

Wi-Fi is considered as one of the most cost effective Access technologies to support 5G use cases. In a heterogeneous network with presence of multiple access technologies, it is necessary for each access network to interop with each other seamlessly by maintaining the same level of quality of service for the end user. More and more **convergence of Wi-Fi & 5G network deployment in enterprise** is going to take place. With Private 5G becoming dominant, use of Wi-Fi radio for access will be a preferred option for many use cases.

**Wi-Fi Sensing** is a new technology which enables motion detection, gesture recognition as well as biometric measurement by using existing Wi-Fi signals. It creates new business opportunities for service providers in the home security, healthcare, enterprise, and building automation & management segments. A standardization effort as IEEE 802.11bf is in progress under IEEE 802.11 WG in the form of the WLAN SENSING Task group.

It is expected that most automotive services revenue will come from in-vehicle infotainment services. Automobile manufacturers globally, that have integrated telematics into their vehicles can utilize Wi-Fi today and generate significant revenue for a number of use cases, including predictive maintenance and repairs, as well as over-the-air (OTA) firmware updates. The connected and autonomous driving vehicles market is driving the evolution of the vehicular industry and is growing at an eight-year compound annual growth rate of 22.3%, 5 times faster than the overall car market. The business opportunity for connected vehicles is significant, with the global market expected to grow to over $212 billion by 2027.
India has witnessed significant progress in internet penetration in the last couple of years, primarily on the back of smartphone growth and falling data prices. Broadband connectivity is considered a key catalyst in the economic and social development of a country. As per TRAI’s recent report, the total base of internet subscribers in the country increased from a total of 238.71 million in 2014 to 776.45 million in 2020, registering a CAGR of around 22%. The data usage per user per year in GB has increased from 3.24 GB in 2014 to 141.11 GB in 2020. At the same time, the data cost to subscribers per GB in rupees drastically fell from Rs. 269 in 2014 to Rs. 11 in 2020. While India has made significant development in internet penetration over the years, there is still a large scope for growth in speeds and connecting the unconnected or poorly connected. Addressing this can enable further growth of technology platforms, businesses, and socio-economic development leading to accelerated economic growth. The COVID-19 pandemic has further accelerated India’s already rapid pace of data consumption and broadband penetration. However, a large segment of the society still remains to be connected.

One of the ways to connect the unconnected is through public Wi-Fi hotspots. Deployment of Wi-Fi hotspots can also provide an alternate mechanism to access the internet on the move or as and when required, without subscribing to a fixed plan. Efforts are being made to create hotspots in the country by Telecom Service Providers and Internet Service Providers.

For instance, CSC, a special purpose vehicle (SPV) of the Central government has deployed more than 1,65,000 Wi-Fi hotspots under the Wi-Fi Choupal program in India. Recently, DoT has allotted a project to CSC to deploy 1 Wi-Fi hotspot and 5 FTTH connections each in 39436 villages in the State of Bihar. Earlier, USOF (Universal Service Obligation Funds) had allotted a project to BSNL to deploy 25,000 Wi-Fi hotspots at rural telephone exchanges of BSNL. In the last five years, Indian Railways has commissioned Wi-Fi at 6,000 railway stations in partnership with Google, DoT, PGCIL, and Tata Trust, with more than 17000 Wi-Fi hotspots. There are Wi-Fi hotspots deployed by Telecom operators mainly to serve their own subscribers through offload or direct access on the mobile number. As per a Wi-Fi Now report in 2020, JIO had already deployed 2 lakh plus Wi-Fi hotspots in India.
As per Cisco's annual internet (2018 to 2023) report, Wi-Fi speeds from mobile devices will triple by 2023. Globally, the average Wi-Fi speeds will grow from 30.3 Mbps in 2018 to 92 Mbps by 2023. Wi-Fi hotspots will grow four-fold from 2018 to 2023. Globally, there will be nearly 628 million public Wi-Fi hotspots by 2023, up from 169 million hotspots in 2018. Wi-Fi 6 hotspots will grow 13-fold from 2020 to 2023 and will be 11 percent of all public Wi-Fi hotspots by 2023. By 2023, APAC will have 49 percent of all networked devices mobile-connected and 51 percent will be wired or connected over Wi-Fi. By 2023, APAC's average Wi-Fi speeds from mobile devices will reach 116 Mbps, which represents 3.4-fold growth from 2018 (34.5 Mbps).

Therefore, it is clear that Wi-Fi hotspots will play a major role in providing broadband services in the country. The National Digital Communications Policy (NDCP 2018) has also highlighted the importance of ubiquitous Wi-Fi hotspots in the country to accomplish the Strategic Objectives of provisioning of broadband for all and deployment of 10 million public Wi-Fi hotspots by 2022. It envisages NagarNet to establish 1 Million public Wi-Fi Hotspots in urban areas and JanWiFi to establish 2 Million Wi-Fi Hotspots in rural areas through funding from USOF and Public Private Partnerships. It also emphasizes promoting Open Public Wi-Fi access through Wi-Fi/Public Data Office Aggregators and Public Data Offices in line with TRAI recommendations.

To increase the proliferation of broadband in the country, the Telecom Regulatory Authority of India (TRAI) issued recommendations to the Government on “Proliferation of Broadband through Public Wi-Fi Networks”. Through these recommendations, a unique ‘unbundled and distributed model’ for delivery of broadband services through public Wi-Fi Networks was recommended. The Union Cabinet headed by Prime Minister Shri Narendra Modi approved the proposal of Department of Telecommunications (DoT), based on TRAI's recommendations, to proliferate Broadband through Public Wi-Fi networks under the framework of the Prime Minister's Wi-Fi Access Network Interface (PM-WANI) on 9th December 2020. This framework takes forward the goal of the National Digital Communications Policy, 2018 (NDCP) of creating a robust digital communications infrastructure.

The Wi-Fi Access Network Interface (WANI) framework enables provision of Broadband through Public Wi-Fi Hotspot providers. It consists of elements such as Public Data Office (PDO), Public Data Office Aggregator (PDOA), App Provider and Central Registry. All these elements act as independent entities in the value chain, therefore allowing innovations and creating Wi-Fi entrepreneurs in the country. This unbundling of the Wi-Fi ecosystem provides opportunities to multiple players to participate, interoperate securely and provide seamless internet connectivity at an affordable rate. It would also spur new business models and innovation, thereby enabling acceleration of the Government’s ‘Digital India’ and ‘Broadband for All’ objectives. The functions of each entity in PM-WANI framework is as follows:
Public Data Office (PDO): It will establish, maintain, and operate only WANI compliant Wi-Fi Access Points and deliver broadband services to subscribers.

Public Data Office Aggregator (PDOA): It will be an aggregator of PDOs and perform the functions relating to Authorization, Accounting and Security.

App Provider: It will develop an App to register users and discover WANI compliant Wi-Fi hotspots in the nearby area and display the same within the App for accessing the internet service.

Central Registry: It will maintain, in accordance with the WANI architecture and specifications, the details of App Providers, PDOAs, and PDOs. To begin with, the Central Registry will be maintained by C-DoT.

The complexity of creating and managing the Wi-Fi network is removed from a PDO (local chaiwala/kiranawala/bakerywala, etc.) and moved to PDOA and APP Providers. To facilitate ease of doing business and encourage local shops and small establishments to become Wi-Fi providers, the Government has not kept any requirement of license or registration for becoming a PDO and no fees are required to be paid to DoT. In fact, PDOAs, who aggregate the last-mile providers (PDOs) also do not require any licence. These PDOAs will only have to register, for which no fees will be charged. Unlike licensed TSPs/ISPs who pay a certain percentage of their revenue as licence fee, PDOAs or App providers are not required to share their revenues with the government.

More than 50 PDOAs and 27 APP Providers are already registered in the ecosystem and around 50 thousand Access point radios have been deployed in a very short span of time. This number is expected to grow exponentially in the near future.

Government has resolved to take broadband to each of the 6 lakh plus villages in the country. Our Hon’ble Prime Minister has announced that all six lakh plus villages will be connected by fiber in 1000 days. While the planning and execution work is in progress, Wi-Fi can be used to extend connectivity from Gram Panchayat to villages. Use of Wi-Fi technology to establish point to point and multipoint microwave links in unlicensed 5 GHz band is one of the alternate and affordable technologies to extend the BhartNet fibre pipes from Gram Panchayat to nearby villages. The bandwidth dropped in the village either through fiber or Wi-Fi can be further distributed using Wi-Fi hotspots. These hotspots can be made PM-WANI compliant to provide various services in the village. Deployment of such infrastructure is already underway in the country by C-DOT on a pilot basis. Please refer to the figure below.

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C-DOT, an autonomous body and Research & Development wing of the Department of Telecom, has developed a range of indigenous Wi-Fi products and solution portfolios ranging from Wi-Fi Access points supporting 11n, 11ac and latest industry standard 11ax (Wi-Fi 6). Along with Access points, Wi-Fi Access controller, AAA, EMS and NMS functionalities are also readily available for any manufacturer and system integration to take technology, mass manufacture and deploy in Indian networks. C-DOT has developed multiple innovative solutions such as Solar Wi-Fi, Long Range Wi-Fi, High Speed Access points (HSAP), Public Data Office (PDO), WAYU (WANI Accessibility Unit), WAP, Satellite Wi-Fi, Balloon Wi-Fi, Bamboo Wi-Fi to provide affordable connectivity in urban, semi urban and rural areas.

C-DOT is also architecting and evolving the WANI framework and offers its WANI complaint Access points (Indoor and Outdoor), PDOA and APP Provider as a Platform to any PDOA and APP Provider to enroll their services in the PM-WANI network.

C-DOT has also generated Indian intellectual property Rights (IPR) in the Wi-Fi domain and filed multiple patents. Indian patent offices have already granted two patents in the area of Wi-Fi technology namely “Dynamic Channel Selection In IEEE 802.11 Networks” and “Method and System to Broadcast Emergency Alert Message Using IEEE 802.11 Based Wi-Fi Access Point”. C-DOT has also published case studies on World Wi-Fi Day in 2018, 2019 and 2020.
The WANI standard is currently implemented in India which has the second largest subscriber base of internet users in the world. WANI framework is built to ease the deployment of Wi-Fi networks by local, small and medium entrepreneurs with very small investment. The complexity of running a Wi-Fi network is removed from these small business owners and moved to an aggregator model similar to Ola/Uber/UPI model. This framework provides a new business model to make Wi-Fi sustainable by distributing the Capex and Opex to multiple players and bringing down the cost of ownership for a single player.

Given the benefit of the PM-WANI framework, there is ample opportunity to replicate this model in other countries by globalising these WANI standards. The global platform such as IEEE SA helps in adoption of the standard in non-discriminatory way in any region. The standard process helps to evolve the framework to meet various requirements which may be specific to particular regions. The standard process also helps in developing technology expertise in other regions. There may be constraints to adopt a country specific framework, but it's always easy to adopt it through global standardization and collaboration effort. C-DOT is already driving the effort of developing a global standard based on the WANI framework in IEEE SA through the P2872 Working Group also known as Standard for Interoperable and Secure Wireless Local Area Network (WLAN) Infrastructure and Architecture (ISAWANI).

Many other significant standardization activities and technology adoption efforts in Wi-Fi are driven from India at national and global standard platforms such as IEEE, WBA, TSDSI, TEC, etc.

**IEEE SA P2061 (Frugal 5G)** focuses on Architecture for Low Mobility Energy Efficient Network for Affordable Broadband Access. This network is referred to as the Frugal 5G network. **The Rural Wi-Fi project** at WBA has a scope to deliver a whitepaper on the present scenario of Wi-Fi deployment in rural areas with focus on India, open to incorporate as well other areas, and identify challenges and gaps in existing Wi-Fi strategy, architecture and guidelines. The work is led by C-DOT and Facebook. **Rural Broadband Service Architecture (RBSA)** project is in progress in TSDSI to define an architecture and technology choice in providing broadband to citizens in Gram Panchayats and villages, focusing on the service delivery aspect with the aim to increase the utilization of infrastructure such as BhartNet. C-DOT has also presented a requirement of supporting **Emergency Alerts** in Wi-Fi standard to IEEE 802.11 WG and currently working in IEEE 802.11bc (Enhanced Broadcast Task Group) to support Emergency alerts use cases.
Many initiatives have been taken by the government to increase broadband penetration and promote Wi-Fi in the last mile. Currently we have only about 0.4 million hotspots against a requirement of 8-10 million hotspots to be on par with the global average. The government has rolled out various schemes and brought out regulatory and policy reforms to address the impediments in increasing broadband penetration at affordable rates. However, constant interaction with stakeholders is necessary to identify implementation roadblocks to fast track broadband deployment and strengthen the internet ecosystem in the country. This will give impetus to the Digital India Initiative of the government, promote innovations in multiple sectors and spur economic growth.

The PM-WANI scheme has taken off well and it is expected to grow exponentially. For the scheme to pick up, many issues need to be resolved. As this is a new and innovative scheme, efforts are needed to create wider awareness about the novel scheme, its technical design, utility of Public Wi-Fi services and associated benefits. For easy availability of WANI compliant devices in the market, vendors can be encouraged to seek TEC certification. TEC certification for WANI compliance can facilitate off-the-shelf equipment for faster deployment. However, there should not be mandatory requirement for TEC certification. There is a possibility of vertical squeeze as TSPs who are wholesale providers of bandwidth to PDOs are also retail players themselves. Therefore, there is a need for fair, reasonable and non-discriminatory pricing rules for bandwidth. A regulation prescribing ceiling rate with guaranteed QoS can be considered by TRAI to ensure that ISPs/TSPs do not exercise discriminatory practices in allocating bandwidth and pricing for PDOAs/PDOs under PM-WANI. Several thousand entrepreneurs are expected to take the scheme forward, and many small entrepreneurs will find it difficult to scale up the business due to lack of access to capital at reasonable terms. The investment for a PDO to establish a public Wi-Fi hotspot is around Rs. 8000 with a breakeven of around 6 to 8 months. Even this amount is difficult for many PDOs who are small entrepreneurs. For 1 million hotspots, this translates to investment of around Rs. 8 billion and creation of many small entrepreneurs. Government could facilitate schemes for micro-financing with tie up with banks or partial funding from USOF for small entrepreneurs to invest in PDO/PDOA business
under PM-WANI. Roaming between different PDOA locations is one of the key requirements so that the customer is not restricted to a particular location or area served by a PDOA from which it has purchased the service. Suitable modifications can be made in the WANI framework to enable roaming among PDOAs.

Affordable data demand is exponentially increasing which is supported by an affordable device ecosystem, availability of a variety of quality content, OTT services, e-education, healthcare, etc. and many new use cases. Covid-19 has fueled this demand further multifold. Higher population density in the country puts additional demand and limitations on capacity of the network. Telecom Service Providers (TSPs) in India have far less licensed spectrum for mobile services than those in other countries. Furthermore, the quantum of unlicensed spectrum in India is far lower in comparison to several other countries. India has around 689 MHz of spectrum in the 2.4 and 5 GHz bands available for unlicensed use, spread across various spectrum bands compared to around 15000 MHz (in the 2.4, 5, 6 GHz and Vband) in countries like the USA, China, Japan, UK, etc. Telecom operators are also utilizing the Wi-Fi technology to offload their subscriber activity to unlicensed bands so that they can keep the Capex low and maintain the quality of service for more real time applications.

Existing 2.4 GHz band has already been crowded, and the 5 GHz band is likely to be crowded soon. To support evolving use cases and data demand, it is very important to explore opening up additional bands for unlicensed usage. To increase the capacity, Wi-Fi now has standards in the 6 GHz (Wi-Fi 6E) and 60 GHz band (a variant of Wi-Fi also called Wi-Gig). This allows for higher bandwidth channels, greater number of channels and higher speeds. Many countries have opened up additional spectrum in unlicensed bands to meet increasing demand. The United States Federal Communications Commission (FCC) approved opening up the 6 GHz frequency band for unlicensed use by Wi-Fi 6 technology in April 2020, a decision many called historic. Similarly, countries like the UK, South Korea, Chile, Brazil, Canada, Morocco, Peru, Saudi Arabia, UAE and European Union have opened up the 6 GHz band as an unlicensed band. The ability to leverage the 6 GHz band for unlicensed Wi-Fi operation — referred to as Wi-Fi 6E — will deliver faster connectivity speeds and improved capacity. Similarly, a major part of V band (57 to 71 GHz) has been delicensed in about 70 countries of the world to increase capacity and accelerate economic growth. There is a need to explore releasing these bands in the country at the earliest to unlock economic value from these bands by providing broadband access through Wi-Fi using these bands.

Telecom products play an important role in the larger vision of “Digital India”. While the production of electronic goods in the country has increased from $29 billion in 2014-2015 to $70 billion in 2018-2019, the trade deficit has also increased from $32 billion to $48 billion in the same period. Given the huge market size of India, and availability of the right talent, various telecom products including Wi-Fi products can be produced in India to meet local demand and export to other countries. To promote indigenous manufacturing, the Government has notified PMI (Preference to Make in India)\textsuperscript{39} and recently PLI (Productivity Linked Incentives) Policies\textsuperscript{40}. The PMI policy is to leverage the large domestic market to nurture domestic companies, making available the market access to the domestic companies and enabling them to scale up their production and also become competitive. PLI (Production Linked Incentive Scheme), with the objective to boost domestic manufacturing, investments and export in the telecom and networking products has been notified recently with an outlay of Rs. 12,195 Crores over a period of 5 years. The scheme envisages to create global champions out of India who have the potential to grow in size and scale using cutting edge technology, and thereby penetrate the global value chains. However, issues related to easy access to capital, improving associated infrastructure, quick product certification, removing trade barriers, offsetting cost barriers, cross-checking local content in so-called ‘Made in India’ products, etc. are required to be addressed on a regular basis.
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Role and Importance of Next Generation Wi-Fi Technologies in Acceleration of Digital Transformation