Technology Intelligence & IP Research

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INTERNET OF MEDICAL THINGS

Thematic Report By

Dr. Yogesh Shelke | Arpit Sharma

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01. Introduction

1.1. Study Objective

Internet of Medical Things (IoMT) enables machine to machine interaction and real time intervention solutions which will radically transform the healthcare delivery, affordability and reliability in near future. Additionally, increased patient engagement in decision making will boost the healthcare service compliance. As a result of this, technology adoption rate will increase in coming years to grow this market to reach $156 Billion by 2020.

By providing the individual data driven treatment regimen and optimized devices as per physiological requirement, IoMT will promote personalized care and high standard of living. Moreover, recent research in sensor, networks, cloud, mobility and big data domains, will lead to affordable medical devices and connected health ecosystem. This report covers the in-depth analysis and insights on future aspects of Internet of Medical Things (IoMT) technology.

1.2. Why IoT?

The Internet of Things (IoT) ecosystem has a very complex architecture, in which multiple components interact with each other to enable various solutions for the end user. This is an interdependent system, which enables real-time data acquisition, device connectivity, data transfers, and analytics to control end user applications. IoT provides the connected environment, comprising the cyber physical systems, which integrates human intervention with computer-based systems and facilitates data-driven decision processes.

Currently, IoT encompasses technologies such as smart grids, smart homes, intelligent logistics, and smart towns, augmented through sensor, actuator, and communication protocol networks. IoT offers various real-time solutions through the integration of data analytics and sensors embedded on machines.

1.3. Benefits and Impact of IoMT

In addition to other industry segments such as manufacturing, construction, and power distribution, healthcare is poised for a transformation through IoT. The term Internet of Medical Things (IoMT), a healthcare application of the IoT technology, comprises a network of connected devices that sense vital data in real time. Figures 1 and 2 illustrate the overview of the patient and physician components and potential impact of this technology.

Figure 1: IoMT Components

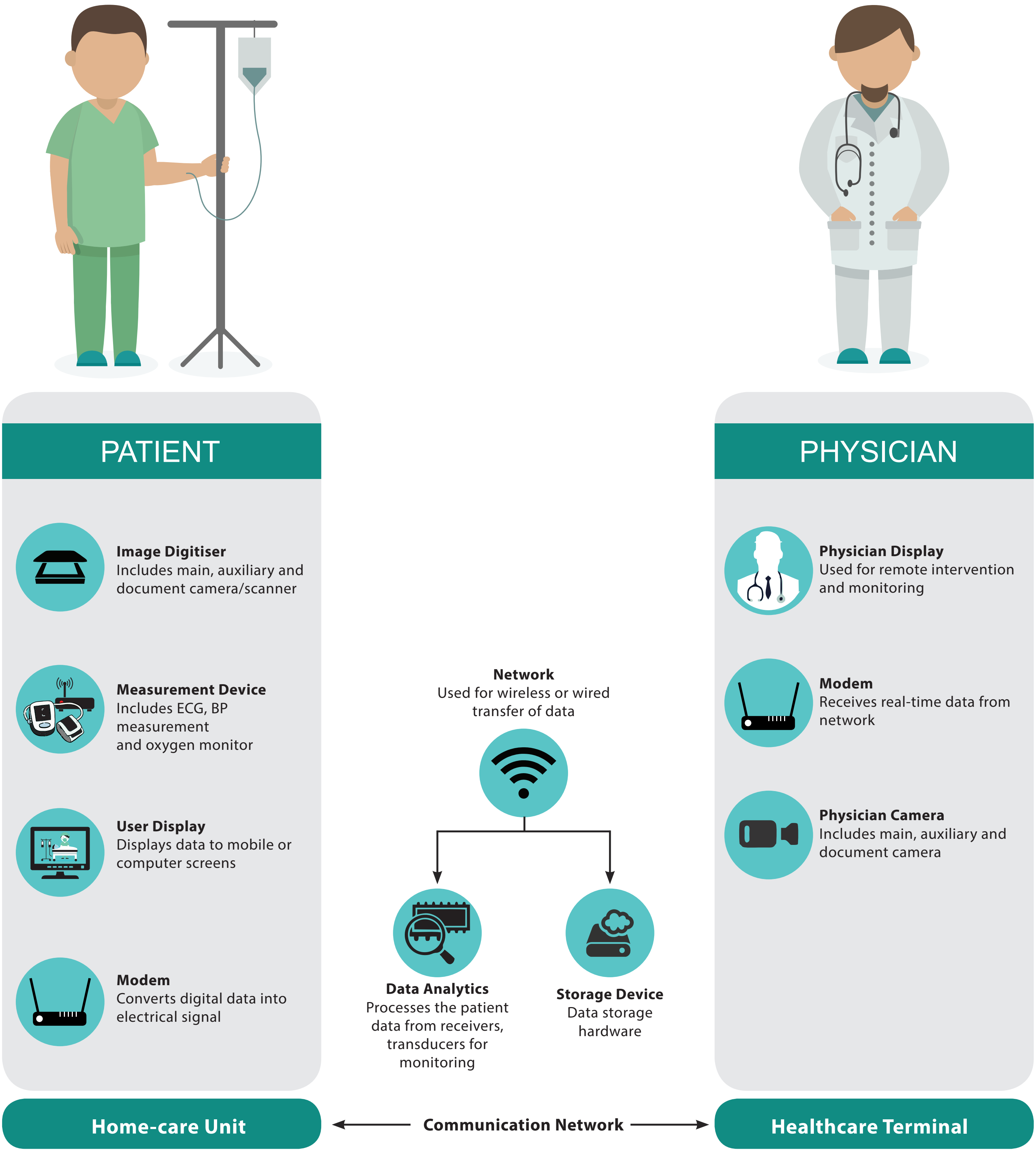
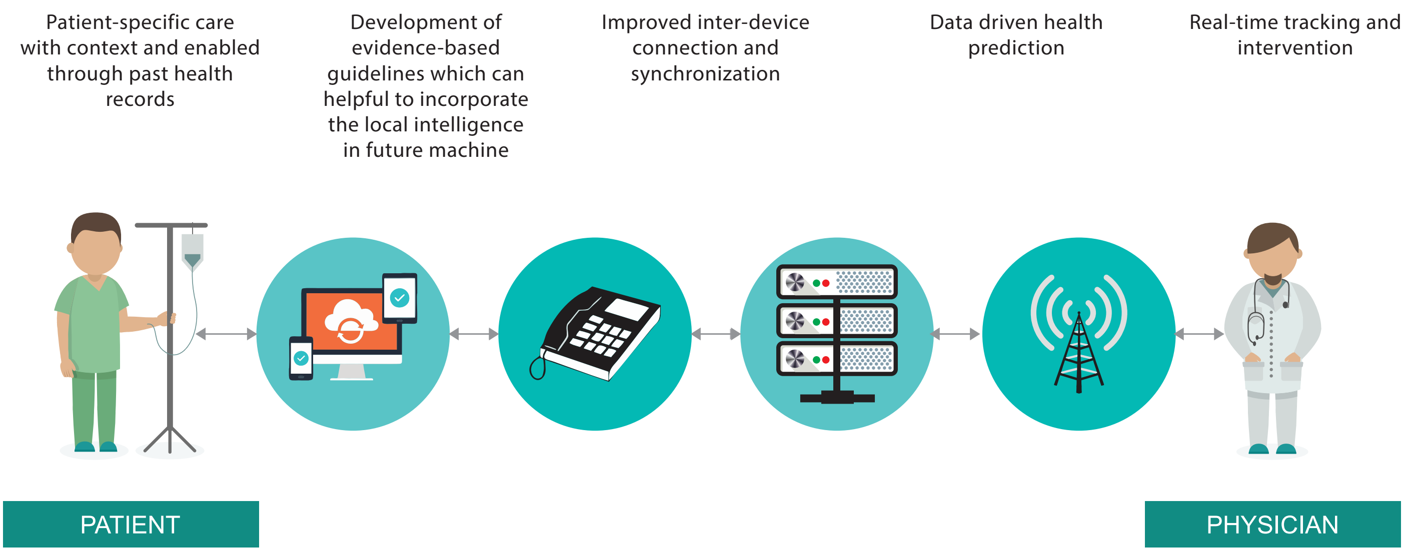


Figure 2: IoMT Impact



IoMT increases human-machine interaction which enhances the real time health monitoring solutions and patient engagement in decision making. Table 1 lists the key benefits and limitations of IoT implementation in healthcare domain. IoT enables the real time health monitoring, data registration and health record maintenance to assist in the data driven decisions. These may provide the personalized health regime for the patient. Figure 2 lists the key impact areas for the enablement of IoT in healthcare.

Table 1: IoMT Advantages and Limitations

Advantages

Patient Benefits

- Real-time interventions in emergency situations
- Cost reduction
- Reduced morbidity and financial burden due to less follow up visits

Health Care Service Providers

- Optimal utilization of resources and infrastructure
- Reduced response time in case of medical emergency

Device Manufacturers

- Standardization/compatibility and uniformity of data available
- Capability to sense and communicate health related information to remote location

Limitations

Technical Challenges

- Security of IoT data - hacking and unauthorized use of IoT
- Lack of standards and communication protocols
- Errors in patient data handling
- Data integration
- Need for medical expertise
- Managing device diversity and interoperability
- Scale, data volume and performance

Market Challenges

- Physician compliance
- Data overload on healthcare facility
- Mobile hesitation
- Security policy compliance

02. IoMT Applications

Existing medical devices can be modified into IoMT devices to sense real-time data for patient monitoring through enhancements such as sensors, signal convertors, and communication modems. IoMT devices have been conceptualized in various forms of smart wearable devices, home-use medical devices, point-of-care kits, and mobile healthcare applications, and are able to communicate with medical experts in remote locations. Apart from their utility in managing regular health statuses, they have also been used for disease prevention, fitness promotion, and remote intervention in emergency situations. Some IoMT end application areas are discussed as follows:

2.1. Chronic Disease Management

IoMT-enabled devices offer promising alternatives to manage chronic morbid disease conditions such as hypertension, cardiac failure, and diabetes. Such devices are used to monitor parameters such as blood pressure, random blood sugar levels, and weight and electrolyte concentrations inside the body. The real-time vital data sourced by these devices is processed at a higher level and used for future treatment alterations and dose changes, and to predict the disease's progress. Furthermore, centralized data collection can be useful in studying the epidemiological trend in particular diseases in a specific population.

2.2. Remote Assisted Living (Tele Health)

Data from network devices is registered at a central location at the physician's office. Compiling and processing patient-specific data enables healthcare automation, which analyzes fresh data against past records and decides the future course to manage the patient. This machine-enabled intelligence helps service providers transfer the tasks of routing, monitoring, and field administration to IoMT machines, thus saving the cost incurred from implementing follow-up resources and infrastructure utilization. Additionally, remote monitoring has led to a decrease in member drop-out rates and increase in healthcare resource productivity. BodyGuardian Remote Monitoring System is one of the commercialized systems used for cardiac monitoring that separates the patient's identification information and observation data to ensure security. Furthermore, encryption protocols are used to transmit and store critical information, which ensures the reliability of the solution.

2.3. Wellness and Preventive Care (Lifestyle Assessment)

IoMT-enabled devices have facilitated health supervision with monitoring systems for diet, physical activity, and quality of life. Innovative devices, such as wearable devices, implantable chips, and embedded systems in biomedical devices track continuous data on patient activity and related vital changes. Advanced sensors, convertors, and firmware in smart devices allow users to analyze and correlate various vital events with health conditions at the local level. Additionally, the remote networking capacities of these devices provide expert assistance in emergency situations at any remote location.

2.4. Remote Intervention

Real-time data obtained from sensors enables physicians to administer drugs and evaluate response in case of emergencies. Such timely interventions offer high-tech medical assistance and reduce the cost of hospitalization.

2.5. Improved Drug Management

IoMT-based RFID tags manage drug availability problems and supply cost. The FDA has suggested guidelines for RFID (Radio-frequency identification) and drug supply chain management. These include the addition of the tags on medication packaging, which enable manufacturers to ensure supply chain quality. Other solutions include adding this technology to medication; WuXi PharmaTech and TruTag Technologies have developed edible IoT “smart” pills, which help monitor drug doses and the patient’s pharmacodynamics. Such solutions may help drug companies mitigate risks and losses during supply chain and administration.

Other application areas:

- Training courses and coaching representation to paramedical staff
- Assistance in rehabilitation and hospitalization
- Access to health information electronic health records (PHR/EHR) without loss of medical information
- Online protein analysis and accuracy of composition

Considering the application areas above, the maximum potential to use IoT-based devices is in the field of chronic disease management. The following table illustrates end-application-wise projected savings due to the use of IoMT devices:

Table 2: Projected Applications and Area-wise Cost Saving

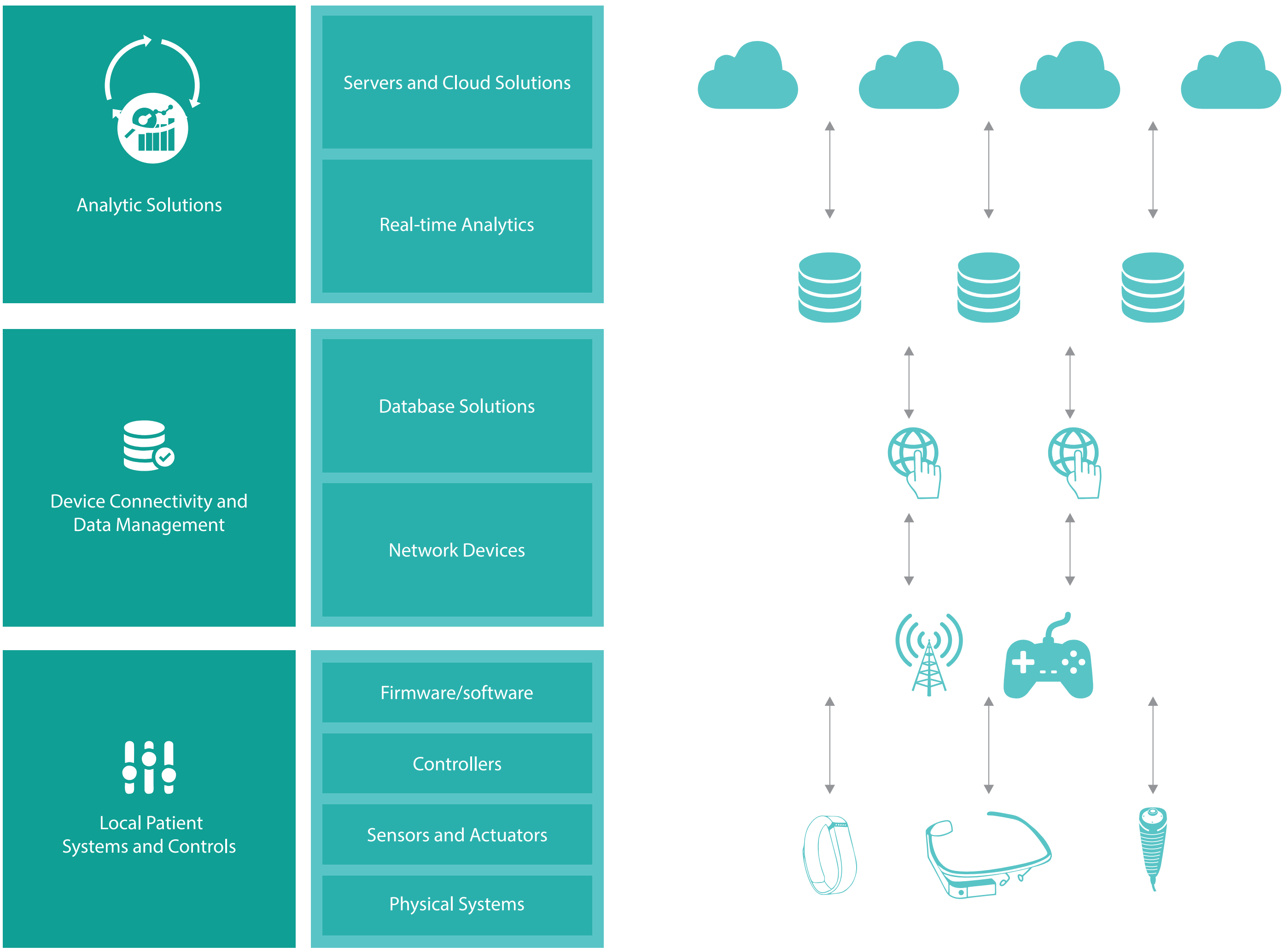
Application Area	Health Conditions/Solutions	Opportunity to Save ($ Billion)	Commercial Opportunity ($ Billion)
Chronic Disease Monitoring	Heart disease, asthma, diabetes.	$ 200 Billion.	~$ 15 Billion
Tele Health	Routine remote checkup, psychological care.	$ 100 Billion.	~$ 12 Billion
Wellness and Preventive Care	Obesity, smoking, cessation, lifestyle monitoring.	Indefinitely Large.	~$ 6 Billion

Refer Annexure for Data Source

03. Technologies Enduing IoMT Implementation

The macro-level IoT architecture comprises three layers: local devices, connectivity, and data analytics and solutions. The structural and functional aspects of each component are discussed as follows:

Figure 3: Architecture of IoMT Systems



3.1. Local Systems and Control Layer

Decentralized intelligence is among the key elements of IoT. In decentralized intelligence, the prime objective is to build a medical device with intelligent control capabilities. This helps in processing operational data at the local level, in addition to the central server. These devices are usually enabled with sensors to measure operational parameters, converters to generate digital inputs, controllers to make real-time decisions based on inputs received from the converters, and network interfaces to share data with other machines / central servers. Examples of such devices are wearable monitors, implants, and physician handheld diagnostic devices.

Compatibility and the integration of advanced electronics are additional factors driving the use of IoT solutions at the device level. Such devices are capable of acquiring qualitative, real-time biometric data from the patient's body and transmitting it under a secured environment to a higher level architecture. Encoders, actuators, and encrypting devices perform data transformations and pass it on to the next layer of the ecosystem (i.e. communication protocols such as NFC and over-the-air programming) for analysis.

3.2. Device Connectivity and Data Layer

The layer primarily focuses on collecting data from the network device and storing it in pre-defined data stores. The technologies at this layer are not unique to any solution (such as patient monitoring).

Secured medical data transfer technologies manage large data volumes and ensure quality during the process. Networking firms such as Cisco and Oracle are quite active in providing advanced technologies to end consumers / system integrators based on requirement.

3.3. Analytic Solutions Layer

Irrespective of the types of healthcare solutions enabled, the central/remote server collects data from multiple devices over the network and their key components. The server with built-in algorithms analyzes real-time operational data to provide insights and conclusions. This data-driven diligence helps with diagnostic ability, disease prediction, and implementing preventive measures.

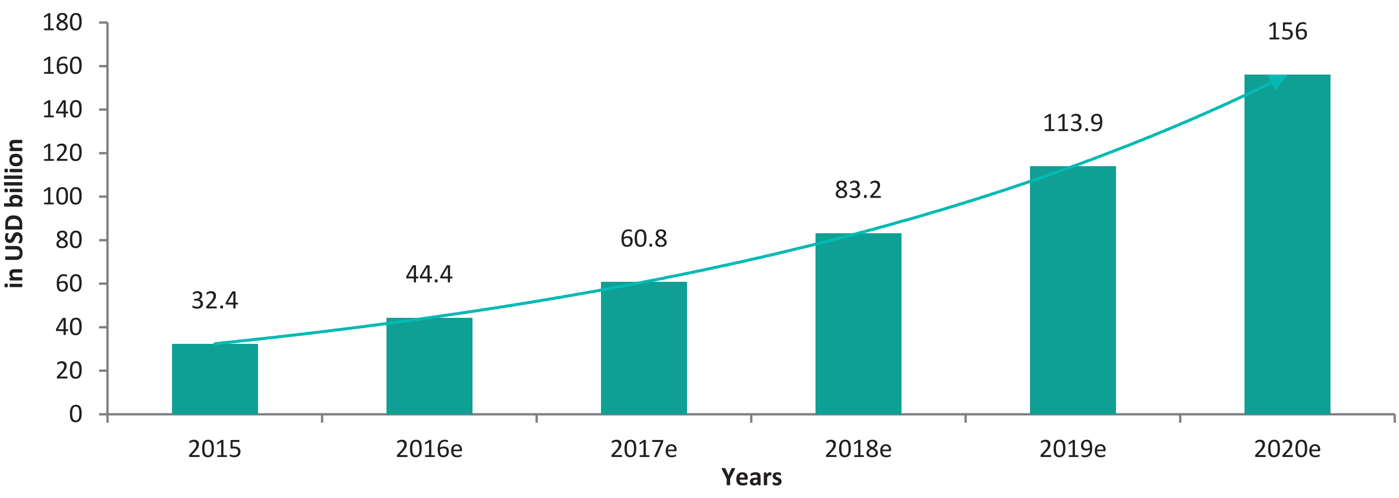
The collective and comprehensive evaluation of data from different sources such as implants and smart devices enables healthcare solutions, such as remote patient monitoring, interventions, and chronic disease management.

04. Market Landscape

4.1. Market Overview

The IoMT market is forecast to expand at a CAGR of 37 % to USD 156 billion by 2020. Technologies used in IoMT can be divided into the three technical classes: local patient systems and controls include sensors, controllers, firmware, and end medical devices; device connectivity and data management comprise networking and database systems; and analytics solutions broadly consist of data analytics and cloud-enabled solutions and services. The major technology contributors in the IoMT ecosystem layers are firms that provide semiconductors and embedded systems; application developers; firmware companies; wireless network operators; data management companies; sensor, tele-presence, and location technology providers; Internet security/privacy and machine-to-machine vendors; IoT service providers; and general telecommunication players. In the current scenario, North America leads the market in the high penetration of medical technologies and government insurance policies. In future, analyst forecast growth of technology in Asia pacific and European market due to increasing awareness, changes in lifestyle, improved diagnostic facilities and disease burden. Other drivers and challenges for future growth are illustrated in Figure 5.

Figure 4: Market Forecast for IoMT



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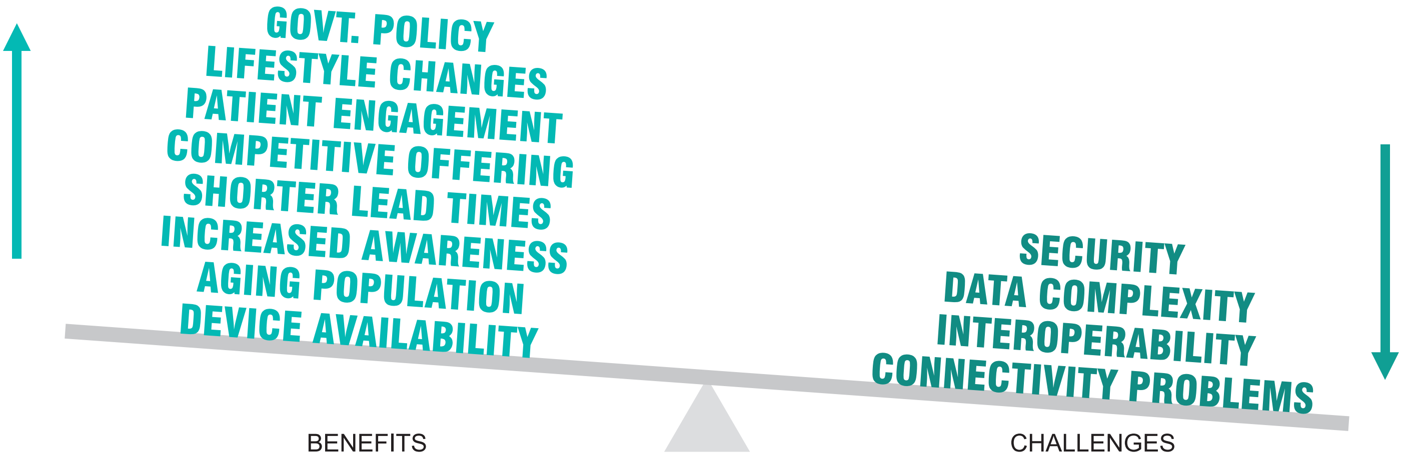
4.2. Key Players and Current Trends in Value Chain

Major companies include Medtronic Inc., Philips GE Healthcare, Cisco Systems, IBM, Microsoft, SAP SE, Qualcomm Life Inc., Honeywell Care Solutions, and Bosch Healthcare. The IoMT market has a range of solution providers that specialize in the fields of patient monitoring (Jawbone, AliveCor), telemedicine (HealthSpot station), medical data capturing (Capsule Technologies), and hospital management (nGage). Moreover, new entrants such as Diabetizer Ltd., Proteus Digital Health, Adheretech, Cerner Corporation, and Physiq are niche players that focus on patient-centric solutions.

Figure 5: Market growth drivers and challenges



Each layer comprises various sub-technologies that interact with each other for data flow between the patient and caregiver. Recent innovations in these sub-technologies are as follows:

4.2.1. Local Patient Systems and Control

Sensor and Smart Patient Devices

The conventional sensing device detects the various physiological parameters based on the potentiometric, accelerometric, and electrochemical principles. These sensors are incorporated within the medical devices and solutions. The recent shift in trend is toward the multi-sensing platform, which comprises a mix of two or more sensors in next-generation, personalized self-tracking devices. Multi-sensor-enabled products such as individual systems can be incorporated into existing devices such as smartphone applications and home automation sensors. Around 80 million wearable sensors and patches are estimated to be in use in the healthcare market by 2017, and smartwatches are likely to comprise about 40% of consumer wrist-worn devices by 2016. Some of the marketed smart-sensing devices are listed below:

Table 3: Smart Patient Devices

Sub Segment	Product Segment / Brand Names	Companies
Smartwatches and Wristband Sensors	Smartwatches Wristband Sensors Jawbone UP wristband Adidas MiCoach Somaxis	Wimm Labs Sony Nike Amiigo
Monitoring Patches	Blood chemistry monitoring patches Zio Patch	Sano Intelligence iRhythm
Others	Augmented eyewear Wearable textiles	Google Hexoskin

Microcontrollers and Gateways

Conventional controllers convert data from the analog to digital format. These devices include converters, which process and analyze the sensor data and convert it into biometric data, and then transmit this through a wireless network. The prime advantage of these devices is they reduce manual errors caused by human intervention. However, automating the data handling process may reduce accuracy, along with operational cost.

Peripheral technologies include graphic displays, controllers, gateways, and communication modems used for wireless data transmission from the patient's location to the physician's office. Some commercialized technologies include remote monitoring platforms (Freescale Home Health Hub); the Sonamba daily monitoring solution, which provides monitoring for the geriatric population (ZigBee®-based wireless connectivity for Sonamba); and the Numera Libris mobile personal health gateway. Future technological innovations are expected to focus on facilitating low power consumption and small device footprint, extending battery life, and furnishing bio-energy harvesting solutions.

4.2.2. Device Connectivity and Data Layer

Network technologies connect patient devices to remote locations and manage data transmission. These connectivity technologies are segmented into Wi-Fi, Bluetooth Low Energy (BLE), ZigBee, cellular, NFC, and satellite.

Some implementations of wired and wireless technologies include Bluetooth® and Bluetooth Low Energy (BLE) (for personal area networks or PANs), used with personal devices, and Wi-Fi® and Bluetooth (for local area networks or LANs) in clinics or hospitals.

4.2.3. Analytic and Solutions Layer

Continuous IOT Monitoring

Continuous patient monitoring provides the real-time tracking, feedback, and intervention of patient parameters based on real-time data obtained from connected devices. The market analyst estimates market growth for this sub-segment to be around USD $21 billion in 2016.

Among the various commercialized platforms is the Masimo Radical-7®, a patient monitor for physicians' offices, which collects patient data and wirelessly transmits for ongoing display or notification purposes. The prime hurdles in enabling these solutions are related to the security and standardization of sensitive medical data across networked devices.

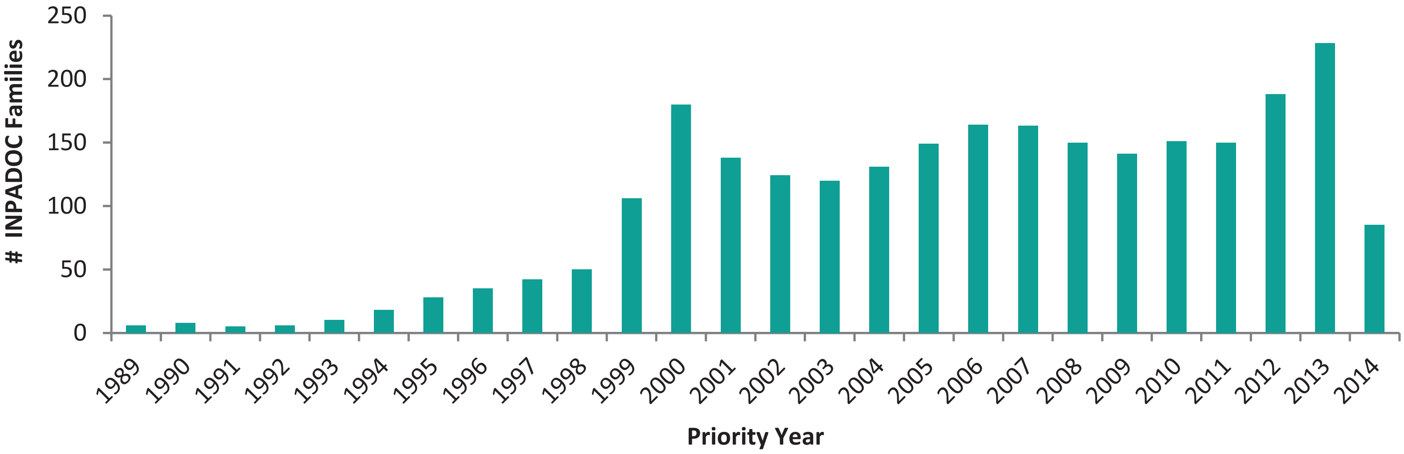
Other data-driven solutions enabled in IoMT are medication management, chronic disease management, inpatient monitoring, and surgical intervention, which stems from remote monitoring.

05. Intellectual Property Perspective

5.1. Intellectual Property in IoMT Overview

The development of telemetric devices was first commenced in 1970 with a patent filed by both Warner–Lambert and Pacemakers Diagnostics clinic of America to disclose the telemetry and telephone transmission link system, to transmit healthcare data to remote locations. However, actual patent filing activities grew robustly after 1989, with the integration of biosensors into existing systems to capture dynamic physiological data and transmit it through wireless networks. The following graph depicts the technological evolution of telemedicine and IoT devices, which comprise a closed interdependent system of networked sensors, protocols, and cloud computing inventions.

Figure 6: Patent Filing Trend in IoMT Technology



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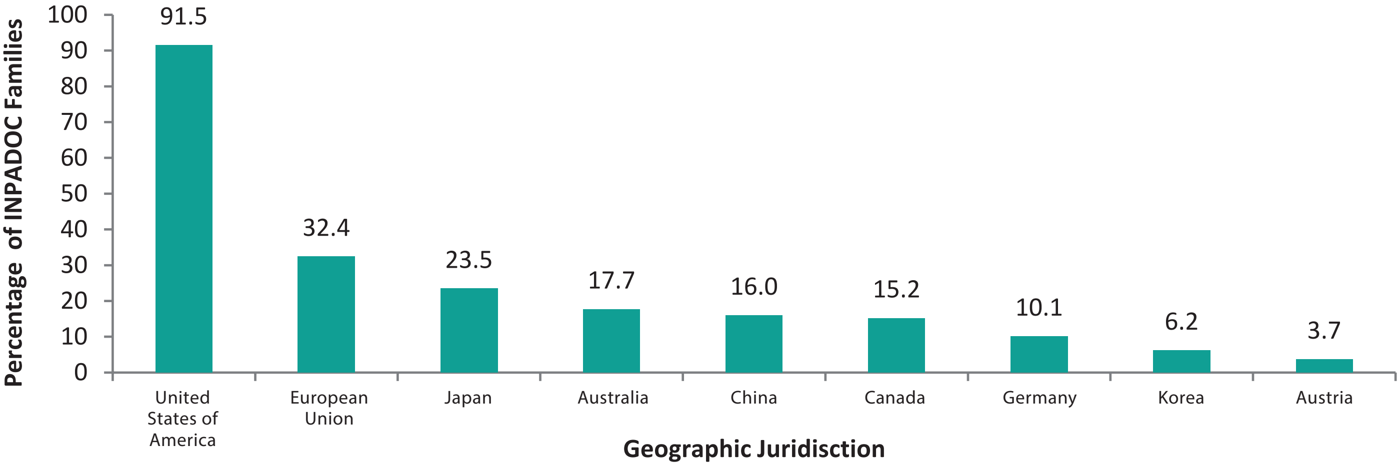
The Internet-based medical device and remote healthcare assistance segments first flourished in the US due to the country's major market share in conventional medical devices. Remote location-enabled technologies were rapidly adapted in the market due to their widespread clinical acceptance and healthcare policies. Due to this, major corporations opted to protect their inventions in North America, followed by Europe. The next graph depicts the geographic coverage of the INPADOC patent families in the global markets:

Figure 7: Geographic Coverage



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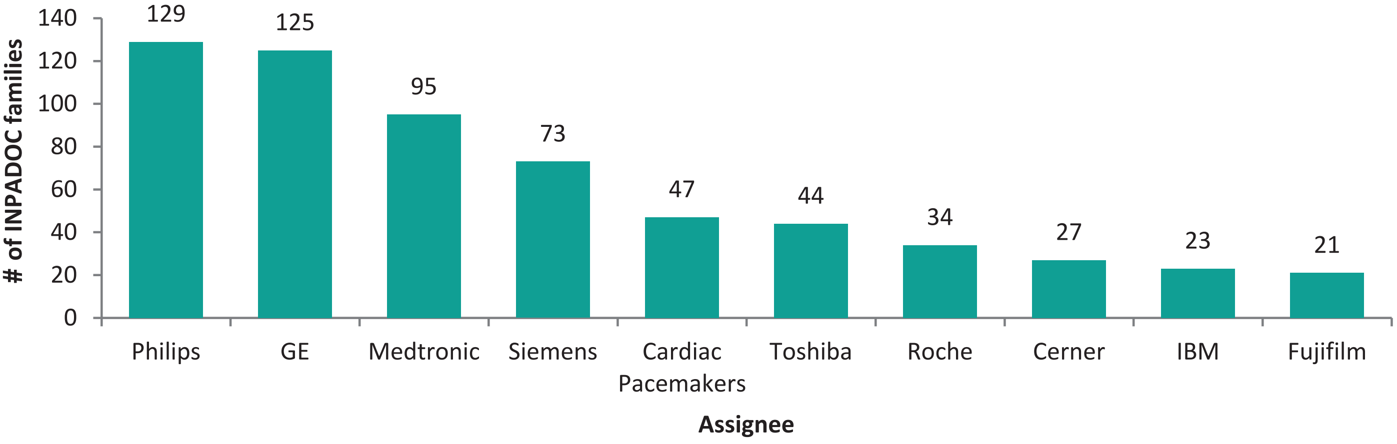
5.2. Key Players

Philips, GE Healthcare, and Medtronic are the leading players in IoMT technology. Philips offers IoMT products that enable cardiac monitoring, remote patient communication devices, and sensors to detect physiological parameters. GE and Medtronic provide comprehensive integrated products that support cloud-based technologies in existing monitoring devices, implants, and cardiac pacemakers.

Figure 8: Top Patent Assignees



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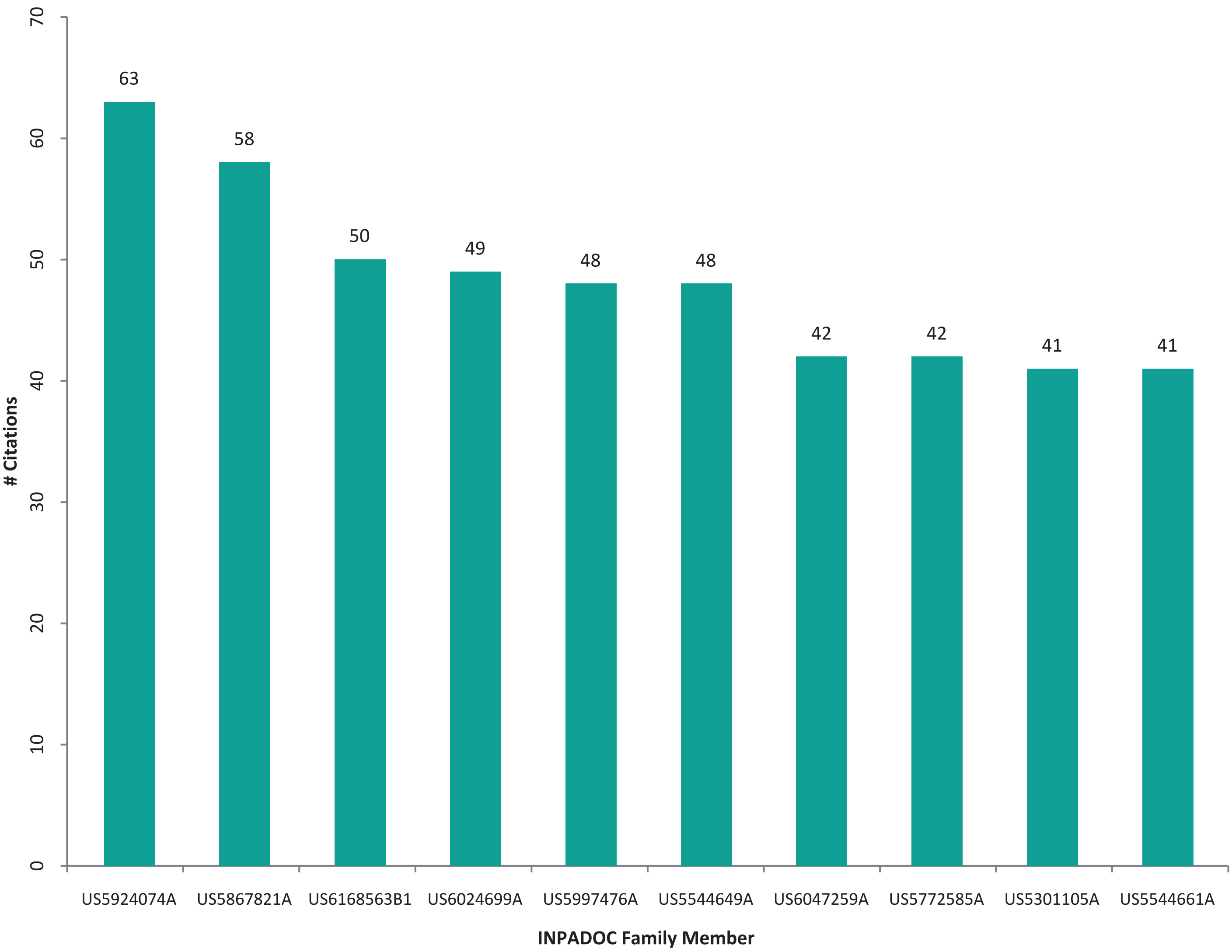
Other players such as Siemens and IBM extend solutions in upper layers, which enable data analytics and cloud-based services to biometric data obtained from physical devices and sensors. Roche and Cerner focus on the integration of smart communication technologies that have the ability to connect diagnostic devices to remote locations.

5.3. Milestone Innovations

Key technological innovations are classified under the medical data handling (US5924074A), remote networking technologies related to medical devices (US5867821A), and data capturing sensor technologies (US6024699A) categories. The following key patents cover the IoMT technology and have been cited frequently:

Figure 9: Key Inventions



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06. Future Prospects and Conclusions

While IoT-based medical technology applications are still in a nascent stage of development, the implementation of connected devices could significantly improve healthcare delivery.

Perhaps the greatest advantage would be an enhanced operational efficiency through a growing use of networked devices. Transparent data flow from lower-level physical devices to the cloud (and associated data analytics) could enable real-time response from remote locations, perhaps saving lives now more than ever before.

Data-driven decision making is likely to empower caregivers to accurately monitor a patient's comprehensive health status, take pre-emptive preventive measures, as well as instantaneously respond to emergency situations. The interconnected systems are forecast to reduce the burden of cost on patients, increase patient compliance, and leverage the advantages of smart devices that can provide instantaneous responsive healthcare.

Although automation in healthcare monitoring would increase operational efficiency, it may pose serious risks during implementation, such as data theft, insecure data transfers, and irregular network connections. These challenges, combined with regulatory hurdles, are projected to drive growth in IoT-based networking and data solutions.

Government initiatives such as the Patient Protection and Affordable Care Act, which focuses on authenticated electronic health record (EHRs), might improve the quality and efficiency of care and promote consistency in caregiving. There is still scope to improve device and international data standards across the industry, which would enable data handling in a consistent fashion.

Considering the benefits and associated challenges, IoMT seems a promising solution to improve healthcare monitoring and treatment outcomes.

By providing individual data-driven treatment regimens and optimized devices as per physiological requirements, this technology represents a new era of personalized healthcare and better living standards the world over.

Recent research and developments in sensors, networks, cloud storage & computing, as well as mobility, and big data analytics have evolved enough to enable the creation of affordable smart medical devices and a connected healthcare ecosystem.

07. Appendix

7.1. Patent Filing Trends IPC Class Definition

The patent publication trend is based on the priority date of the INPADOC family and IPC classes, which cover the majority of the IoT-based technologies used for healthcare services. The detailed class definition includes keyword-based search strategies to cover concepts in IoMT.

» A61B5/0002 - Remote monitoring of patients using telemetry, e.g. transmission of vital signals via a communication network

» A61B5/0015 - Remote monitoring of patients using telemetry, e.g. transmission of vital signals via a communication network characterized by features of the telemetry system;

» A61B5/0022 - Monitoring of patients using a global network, e.g. telephone networks, Internet

» A61B5/0024 - Remote monitoring of patients using telemetry, e.g. transmission of vital signals via a communication network characterized by features of the telemetry system for multiple sensor units attached to the patient, e.g. using a body or personal area network

» A61B5/1112 - Global tracking of patients, e.g. using GPS

» A61B5/222 E - Ergometry, e.g. using bicycle-type apparatus combined with detection or measurement of physiological parameters, e.g. heart rate

» A61H2201/50 - Meant to control set of similar massage devices acting in sequence at different locations on patient

» A61M2205/35 - Range remote, e.g. between patient's home and doctor's office; G06F19/30 M - Medical informatics, i.e. computer-based analysis or dissemination of patient or disease data

» G06F19/32 M - Medical data management, e.g. systems or protocols for archival or communication of medical images, computerized patient records or computerized general medical references

» G06F19/322 - Management of patient personal data, e.g. patient records, conversion of records or privacy aspect

» G06F19/323 - Management of patient personal data, e.g. patient records, conversion of records or privacy aspects on a portable record carrier, e.g. CD, smartcard, or RFID

» G06F19/34 C - Computer-assisted medical diagnosis or treatment, e.g. computerized prescription or delivery of medication or diets, computerized local control of medical devices, medical expert systems or telemedicine

» G06F19/3406 - Local monitoring or local control of medical devices, e.g. configuration parameters, graphical user interfaces [GUIs] or dedicated hardware interfaces

» G06F19/3418 - Telemedicine, e.g. remote diagnosis, remote control of instruments or remote monitoring of patient carried devices

» G06F19/345 - Medical expert systems, neural networks, or other automated diagnoses

» G06F19/3481 - Computer-assisted prescription or delivery of treatment by physical action, e.g. surgery or physical exercise

» G06F19/363 - Manual data input, e.g. electronic questionnaires or clinical trials; Y10S128/903 - Radio telemetry

» Y10S128/904 - Telephone telemetry

» Y10S128/904 - Telephone telemetry

» Y10S128/92 - Computer-assisted medical diagnostics

» Y10S128/923 - Computer-assisted medical diagnostics by comparison of patient data to other data

Cover image by NEC Corporation of America.

7.2. Brief Profile of Contributors

DR. YOGESH SHELKE
SENIOR ANALYST, TECHNOLOGY INTELLIGENCE & IP RESEARCH

Dr. Shelke has more than eight years of experience in healthcare services delivery and IP research. Furthermore, he has worked in various community hospitals as a Medical Officer on projects in preventive and social healthcare, especially for oral and gynaecology patients. His area of interest lies in implantology and prosthesis.

Dr. Shelke has completed his master's project in total knee orthoplastic implants designing. He pursued Bachelors of Medicine from Government Medical College, Miraj, India, and has a master's degree in biomedical engineering and management from Indian Institute of Technology, Mumbai.

Dr. Yogesh has worked on the clinical perspectives of this report.

ARPIT SHARMA
MANAGER, TECHNOLOGY INTELLIGENCE & IP RESEARCH

Arpit has over five years of experience in intellectual property management and patent analytics. His technical interests lie in electronics including power systems & traction control and power electronics. As academic project, he developed an variable field electromagnetic cage to study wound healing in rodents. He has worked as a lecturer in the Department of Electrical Engineering, Thapar University, Patiala.

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