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A Telemedicine Platform for Disaster Management and Emergency Care

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Abstract

Disaster or emergency can create unusual circumstances. And usually they are extremely hard to stop. However, an intelligent approach or strategy can limit the damage or causalities and can help in the restoration of the victims. The technology platform is promising for disaster management. But due to continuous innovation and shift in technology, one single platform for disaster still lacks to be settled that promise less depravity. Telemedicine can blend both technology and medical assistance that can aid in analysis, scalability and potential of a particular plan execution as well as in doing priority protocol practice based on victim's conditions, indicators and diagnosis. Distance from approaching a victim and waiting time can be lessened by a fight-or-flight strategy which is active and rebound since it demands coordination and communication between various sectors for compliance and rebuilding with an intelligent strategy. Telemedicine describes the use of medical information exchanged from one site to another via electronic communications to improve patients' health status and care. Its applications in disaster situation likewise earthquake, war etc., required efficient, reliable communication technology such as GPRS, LTE etc. However, transmission losses or delay occur during transmission. Using Friis transmission condition transmission loses can be minimized for efficient communication. This paper proposed a model where telemedicine technology could be helpful especially in the areas the shortage of medical specialist or doctors.

Keywords Telemedicine · Intelligent strategy · Coordination and communication · Fight-or-flight · Active & rebound · ICT · Wireless network

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1 Introduction

Telemedicine can fit into all disaster conditions by sound strategy and planning. Telemedicine can be used for remote monitoring or provision of care by applying technology platform. Immediate access and prevention to premature deaths or disabilities are very challenging. Telemedicine in disaster management has a potential to provide care if emergency health services, hospitals are terminated by connecting to areas which are less affected and internationally by technology means. Many technological solutions are available, but disaster can indulge unusual situations in which intelligent methods or transitional strategy is required. In case older adults with chronic diseases and disability or critically injured by catastrophe need medical attention and subsequent analysis. The most useful device during such situation is a mobile phone to contact with the closed emergency healthcare service and to get information about the possible treatment [1]. There are many offline applications available to understand the essential information in a critical situation if electricity and other communication references are lost. There are several factors, which become the cause of losses in communication link as shown in Fig. 1 due to fading phenomenon appear in free space propagation of radio signal from base station transmitter to receiver end. Telemedicine system design architecture as shown in Fig. 2. Fundamental elements and stages of a disaster or emergency care management shown in Fig. 3. Cost for affording telemedicine services and devices is pretty less as compared to when these solutions evolved in the market.

National Aeronautics and Space Administration (NASA) first utilized telemedicine strategy in 1985 in Mexico City, and within 24 h voice transmission was confirmed [2]. Military agencies, many space programs and different disaster management agencies are examining several telemedicine services by real or self-generated simulations to see the effectiveness of a distinct service particularly the areas extra porn to a disaster.

This paper presents what could be practical planning for telemedicine in disaster management with recommendations by blending technology and medical area. This article has seven sections.

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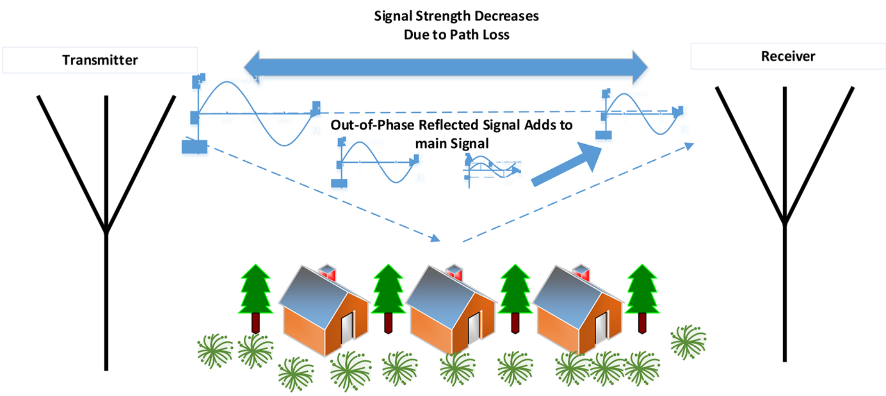

Fig. 1 Transmission losses due to fading in the communication link

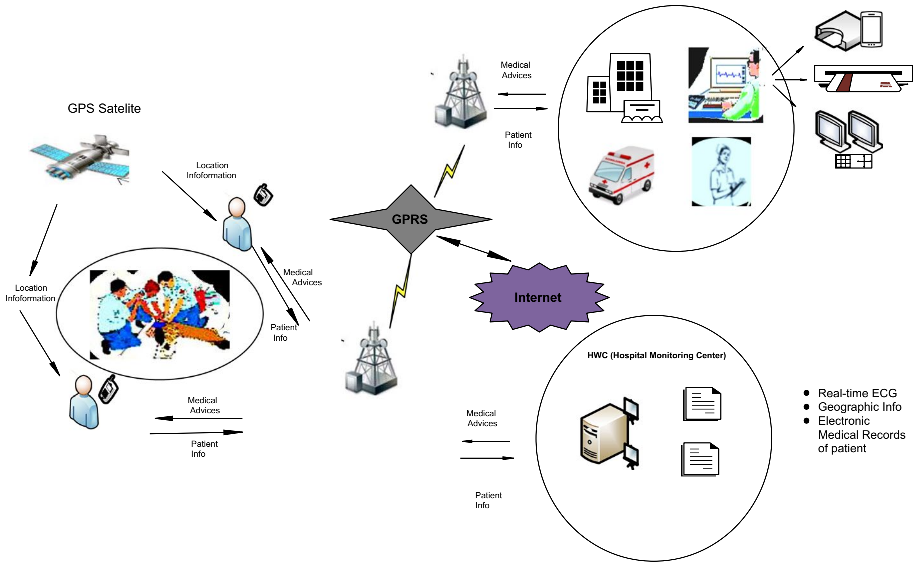

Fig. 2 Telemedicine system design architecture

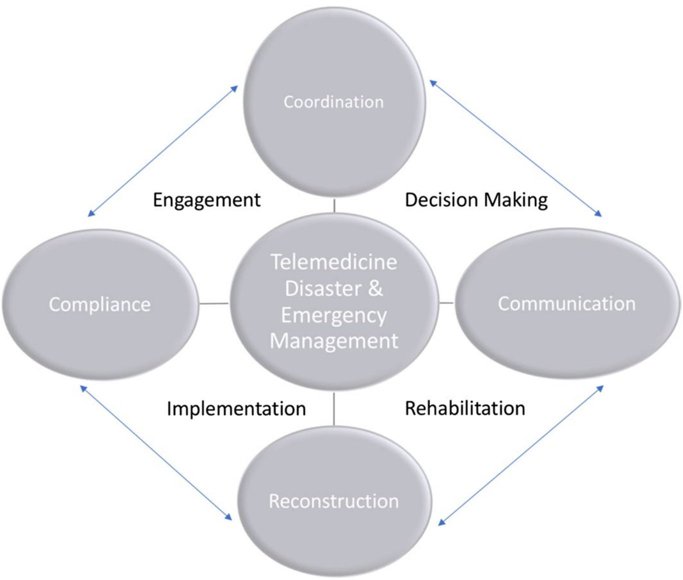

Fig. 3 Illustrates fundamental elements and stages of disaster or emergency care management

disasters, emergency care and disaster risk analysis. Section 2: Telemedicine tools in disaster, indicators and disease conditions in disaster. Section 3: Integrated communication tools. Section 4: Surveillance model has been discussed regarding problematic areas and what are the tools that can guide to making an intelligent, active and rebound strategy for decision making recognizing telemedicine in case of disaster and lastly Sect. 5 conclusions and future scope.

1.1 Causalities, Economic Loss and Types of Disasters

According to World Health Organization (WHO) disaster [3] is a disruptive situation that disorients the functioning of a community and leads to human, infrastructure and a wide range of economic loss that surpasses the actual resources of a particular community to handle it.

Disaster can be categorized as technical, human generated or natural that can lead to damage of infrastructure, physical disability or psychological depression and stress, e.g., cyclone, earthquake, heat waves, floods etc. and it has affected 2.6 billion people from last decade [4]. It clearly shows that still, technology is unable to adequately provide the satisfactory solution for the random and variable situation.

From 1970, 98,000 natural disasters have been estimated that causes 3.7 million causalities and affected 5.8 billion people, and loss of economy Dollars 1.7 trillion throughout the world [5]. In the world, the most exposed and likely disaster region is Asia due to its geographical characteristics. Earthquakes, floods, tsunamis, cyclones are significant sources of significant causalities. It has been estimated and compared that people living in Pacific region are two times effected as compared to African people, 6- times from people living in Latin America, 30 times from North America or Europe from a natural disaster [6].

From the years 1980–2015 annual loss of GDP was highest in these following five countries, Magnolia 20.1%, Belize 9.3%, Maldives 18.5% and Solomon island 8.0% as a share of global GDP due to natural disasters by flooding and storms [7].

Disasters have also been increased from 1998 to 2009 in Europe and according to the European Environment Agency (EEA). These led to the human, economy and overall environment or ecosystem disruption and it clearly demands a correlated risk disaster management & intelligent approach [8]. These disasters have caused approximately 100,000 causalities and create an economic loss of EUR 150 billion.

Most common types of disaster in Europe and America are heat waves, drought, floods, earthquake, thunderstorms, wildfire, extreme winter weather, tornadoes etc. [9]. European Union has adopted the regulation to provide support for the region more prone to natural disasters like earthquake and floods and with this contribution EU will hold 95% of the coast [10]. In 2020 EUR 9.8 billion will be given to support the disaster region.

1.2 Emergency Care and Disaster Risk Analysis

There are four stages of disaster that distinguish how planning should be considered:

- Remission
- Preparedness
- Action or response
- Recovery plan [11]

Before hitting any disaster, it is necessary to study wisely and plan. In a disaster, the infrastructure, connectivity and healthcare provision interrupt when planning is not conducted or improvised. Telemedicine services are appropriate in those countries where the health care system is robust. A disaster has uncertainty, emergency ad threat that affects not only the people but also the services that counter [12].

- It is essential to classify what sets of disaster a country has with a particular region regarding need assessment. What is the infrastructure of communication to support a telemedicine service can be utilized? It can be gathered by local expert opinion, region history and case studies, and framework used according to the infrastructure of a particular disaster-prone area.
- What kind of culture, believes people are having and their eHealth literacy rate. And what is their economic condition?
- Local municipality help to generate data about chronic diseases or disable people number as compared to healthy individuals.
- What types of domestic medical help is available in case of a small or local emergency [13].
- In case of emergency what person should be communicated or notified.
- People in a distinct area should be registered in medical record system so that in case of any disaster identity verification or contact to the closed one be available [14].

These all can help to define parameters to be considered.

2 Telemedicine Tools in Disaster Response

Tools are the devices for linkage between a medical professional and the patient or a person invaded by a disaster for identification, diagnosis, need analysis and provision of a particular treatment through a remote medical health service.

- Live video conference or video broadcast to see or directly consult by the use of audio–video technology like stock data- and- deliver
- to medical professional or help to victims by reliable transmission of information, for example, disturbing images, recorded video and other relevant data to maintain privacy and avoiding panic from relatives
- Remote monitoring and reciprocal actions if the big medical help is not available to a disaster area to make a person alive and engaged.
- Health education is essential about what possibly a Person can do to help severely injured or oneself [15].
- Sending drones which can transmit videos or pictures of a disaster area.
- Connected drones used for emergency supply.

To reduce depression or psychological stress, pain relief or emergency kit for vital signs monitoring and medication provision.

- First aid advice and resuscitation techniques and toxicity guidance

These tools can enhance survival rate, solve difficult condition and causalities.

Table 1 Describes the priority list to indicate the state of the victims involved and priority treatment

Priority	Indicators	Victims state	Condition	Transportation
Priority list 1	Red	Serious	Head injury, severe burns, bleeding, internal injuries, heart attack, breathing problems	Immediate
Priority list 2	Yellow	Moderate to serious	Fractures	Less immediate
Priority list 3	Green	Wounded and can walk	Minor injuries	Waiting list
Non-priority	Blue	Critical	Fatal injuries	No transportation

Table 2 It describes the biological indicators collection during a disaster situation

Telemedicine in disaster	Indicators Collection for the Victims	Heart rate
Tele-education		Blood pressure
Tele-consultation		Oxygen saturation
Medical assistance		Temperature
Tele surgery		Respiration
		ECG 12 leads
		Depression and stress level
		Level of consciousness
		Pulse rate

2.1 The Most General Medical Condition or Indicators in Disaster

The communicable disease can be classified into four different categories based on the infections

For example, through contaminated water, difficulty in breathing or respiratory infections, infections through insect's bites and spreading of infection through multiple injuries [16]. In the case of communicable disease, it is essential that strategy should be defined primarily. It is important through a telemedicine approach to guide and assist patient what important they should do in such kind of complicated situations like primary prevention and early diagnosis (Tables 1, 2).

- Prevention tools include public health measure guidance which should be developed immediately. The outbreak of disease reporting thoroughly with control measures like cholera and tetanus and demand for vaccination, e.g. Animals are carrying contagious disorders like zoonoses or anthrax displacement. Vector-borne diseases, for example, malaria, plague, fever and typhus program working should be immediately started.
- Rehabilitation is the prime factor, and it starts as a disaster happens.
- Water Supply and emergency medication, e.g., chlorination is advisable for water as 0.7 mg/l. It is also advised to follow proper hygiene and avoid the use of water for bathing and other purposes
- Indicators for victims and priority listing tools (Triage)

Triage is a French word that has a meaning to prioritize or sort out for victims that are injured for transportation. It is also called "Special Triage and Rapid Transport" (START). A START is a fast evaluation of treatment only to avoid resources wastage and to focus on Less injured victims [17]. The two below tables describe the priority of victim selection and possible biological indicators that can be seen or reevaluated during the disaster situation [18].

Biological signs are reevaluated as "TRIAGE" to see whether the condition of the victims is improved or regraded.

Significant data analysis and a quick algorithm can help in patient assignment to multiple hospitals their classification for TRIAGE through a system called "MEDTOC" based framework [19]. This system features are enhanced by location prediction.

3 Integrated Communication Tools for Disaster Response

For quick response and recovery, communication plays a vital role in Disaster Management. Communication is integral in four different phases of the disaster as mentioned above. Although technology plays an important role but in floods and earthquake when all the infrastructure lost, trained forces can help more efficiently.

There is an International charter on space primarily for the exchange of information and images in case of disaster and emergencies between different Asian, European and American agencies. This charter has authorized members. Satellite communication snapshots can describe the severity of a particular disaster situation for remote sensing and forecasting of climate changes. Early response to the recovery phase of disaster requires intelligent strategic vision. Application of space technology has been utilized in Mahasen Cyclone in Bangladesh where several causalities happened, and 1.1 million people were evacuated, and only 13 people have lost their lives as compared to Cyclone Bhola and Cyclone Sidr in 2007 in Japan that led to several numbers of causalities [20].

The variable combination of digital tools of Information Communication technology and ICT can help in the rescue, relief operation rebuilding or recovery of the disruptive system in a disaster area. ICT tools can assist in identifying the potential, for example, GIS (Geographical Information system), GPS (Global positioning system) EWS, (early warning system) this system had been used in Japan in 2004 and still their use is in progress. These systems are utilized to give the notification before the hit of disaster [21].

Song GPS oriented prediction method that published in 2007 estimate the energy for the earthquake underwater and predicted the magnitude of the tsunami by a measurement of the sea surface height through NASA satellite. This method is sound from the early warning or prediction method that solely based on seeing the location and depth where an earthquake had happened to predict the size of the tsunami [22].

In a disaster communication system can be restored by using LET (3G, 4G, or future 5G) based wireless networking system a reliable network for communication during a disaster situation. It is a requirement in the disaster that the communication system should be safe, implementable and secure the linkage between variable networks deployed for user mobility [23]. Wireless sensor network system can also be utilized for efficient monitoring of disaster or crisis. A divided network system gives the flexibility, but lack of one fixed protocol leads to many security issues.

Indian institute is researching within a project name DiSARAM [24]. Peer to peer data system by using humans as carriers by using smartphones in case of WiFi service is not available. When they start to connect with WiFi within the range, their movement pattern grants help to communicate and to make a peer to peer connection, and if a smartphone is not available, then the placed routers provide data electrically due to human movement.

Drones are utilized for monitoring with a camera attached, but these can also be used to carry different types of devices and utilities for short distance delivery.

Drones or remotely piloted aircraft systems can produce images of the disaster area with real-time high resolution. These can also be helpful in mapping a particular area. Drones can enhance the prediction and assessment analysis. The time frame of 72 h after a disaster is critical for search and rescue operations in case of telemedicine services. Drones can reorient the damaged communication and can provide help in search of lost, injured people. These can also be employed for media coverage. UAVs can stay in the air for 15–20 min, so it is essential to use them adequately [25].

Drones can also be useful in the provision of emergency kits or communication devices as part of a telemedicine service in case of disaster or emergencies. A case has been studied to see whether an emergency ambulance is faster or a drone and after 18 consecutive flights of drone with an approximate distance of 2 miles [26]. It has been estimated that delivery of drone is fast as compared to the ambulance.

Drones can also be equipped with audio and video system in case of medical assistance. Google glass and other ICT technology can increase the benefits of the drones if we can change their flight time. Drones can be utilized in delivering blood sample in remote areas for surgeries. Drones have rescued many people in earthquake incident in Nepal after 2015 [27]. Matternet drone can carry around 4.4 pounds and transport to 10 km, travel time up to 40 km/h and these drones takes approximately 18 min from off to landing. These drones can create a path separate from the airport, significant buildings and public areas. Zipline is utilizing drone systems to deliver vaccine to 20 clinics in Rwanda [28].

Drones are the applicable and efficient device for the emergency or in disaster as they can carry an essential item, sensors, and communication devices for a small distance [29]. Their use for carrying different items is difficult as travel distance and weight constraint and their use have been checked for travel distance and weight bearing models.

Drone technology is up-and-coming if we can increase the time of flight and pre-load capacity it could be the precision delivery approach as the camera, google glass, wireless devices are attached to get the location and indicators about the victims. Medication and essential emergency items can be connected with drones to avoid significant wastage that mostly happens in the rescue operation by using helicopters. Ambulances and medical team as the entry to target place is challenging especially in an earthquake and floods. For targeted delivery of care and to optimize medical team strategy to victim's drone is a promising way.

4 Surveillance Model (Fight-or-Flight, Active or Rebound Approach)

This model interlinks four different parameters that consolidate a strategy and help in Decision making in the period of disaster or crisis. Big data analytics can enhance data mining to guide people engaged in delivering aid and establishing a framework which is technology based on improving commitment, plan implementation and final restoration of the victims in the disaster area.

Model is divided into four parameters if not precisely managed can limit the application of telemedicine service from locating to the provision of appropriate help to the victims stuck in a disaster.

4.1 Disaster Coordination Tool

Disaster can bring several challenges that require coordination from many emergency departments, e.g., fire, rescue operation team, technological department, Government, private and public support. First 60 min of a disaster is very challenging.

And there is a need for an intelligent strategy that can interlink these all disparities. As one system depends on the evaluation of the other system, it is necessary to be preplanned through simulation approach where you can already assume a disaster with predictive possibilities and commitment of different departments can already be defined. Lack of information can amplify the circumstances and wrong decision making. Telemedicine services should be involved as it is necessary to reduce injuries progress, mortality, morbidity as well as infections. Lack of knowledge, work stress, unwillingness to work with others, inconsistency and conflict can make the situation worse.

4.2 Disaster Communication Tool

For active strategy and deployment of technological tools it is imperative that communication between different department should be appropriate, e.g., what kind of sensors, devices, wireless communication system or network or drones could be used. Communication link establishes via transmitting and receiving antenna as shown in Fig. 4.

The power P of the plane wave incident on the receiver antenna at a distance "R" from the transmitter antenna is given by:

$$P = \frac{P_t}{4\pi R^2} \tag{1}$$

If the transmit antenna has the gain in the direction of the receive antenna given by G_t, then the power equation above becomes:

$$P = \frac{P_t}{4\pi R^2} G_t \tag{2}$$

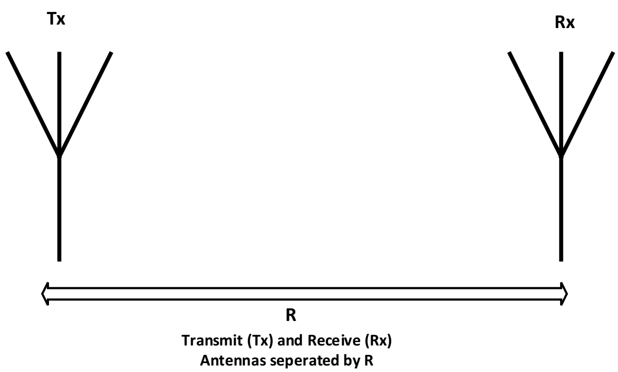

Fig. 4 Transmitting and receiving antenna

Assume now that the receive antenna has an Effective Aperture given by A_{ER}. Then the power received by this antenna is provided by:

$$P_R = \frac{P_t}{4\pi R^2} G_t A_{ER} \tag{3}$$

Effective Aperture can also be expressed as:

$$A_e = \frac{\lambda^2}{4\pi} G \tag{4}$$

Resulting received power can be written as:

$$P_R = \frac{P_t G_t G \lambda^2}{(4\pi R)^2} \tag{5}$$

This above expression is known as Friis Transmission equation.

$$P_R = \frac{P_t G_t G c^2}{(4\pi R f)^2} \tag{6}$$

This above expression is known as Friis Transmission equation in the frequency domain, where The term $\frac{1}{(4\pi Rf)^2}$ is called the free space loss factor. The loss in establishing a communication path is the difference between received power and transmitted power if losses increase it will degrade the quality at the reception. Friis transmission equation relates to power received to the power transmitted between two antennas placed in far-field of each other. The reliable communication link can be established by proper adjustment of transceiver distance so that minimum losses appear with high directivity of the antenna and better signal to noise ratio can be obtained at receiving end for smooth communication.

It can be possible through communication and the use of proper data mining techniques and analysis. Action from multinational telemedicine services can act fast and solve intricate puzzles if the answer is not possible through a national or local team. Communication should follow privacy and security obligations which is a big challenge but only through sound and reliable network system is possible. Lack of one particular platform, suspension of information, response and understanding of handling parameters should be considered. Big data analytics or data mining can help in the analysis of past incident and plan of access to the individual victim to aid in decision making.

4.3 Disaster Compliance Tool

Whatever information is collected, it is indispensable that it should make compliance with the decision for a strategy to be followed. A victim's current synopsis and condition detection through telemedicine service and after coordination between concerned people, compliance can verify the effectivity of tools as mentioned above about the kind of help that can aid or relief patient is made and confirmed by the following compliance. Compliance is examined by different parameters associated with patient condition and satisfaction of the victims.

4.4 Disaster Reconstruction Tool

Reconstruction can have various dimensions that can be seen through different parameters and victims' satisfaction.

It comprises

- Behavioral patterns improvement
- Stress and vital sign reduction
- Engagement with the deployed strategies
- Motivational spirit level
- Patient overall condition improvement
- Responsibility performance and analysis
- Personal and disaster data construction for future misshaping.
- ICT tools and communication network analysis regarding performance
- Business model development for rehabilitation and technology deployment in case of crisis for public and private partnerships.

5 Conclusions and Future Scope

Telemedicine can give appropriate medical help in disaster management, but due to transition and continuous development in technology, there is a need to specify a distinct strategy to be followed. For likely outcomes coordination and communication between public and private agencies is recommended especially in critical hours. There should be consciences between all agencies to generate a standard platform with responsibility distribution approach. eHealth literacy is very vital, and if all the agencies have the proper knowledge, then they can supervise victims in a crisis. There is a need to see what kind of technology or ICT solution can provide terminal aid by examining security and privacy matters as standards are still in the line of the verification. What is recommended is to build a local body of blended staff from medical to technology which is familiar in disaster-prone areas. It can understand the local system, culture, disparities, economy and accordingly create priority coordination, e.g., disaster management care hub with training, hiring and help delivery care strategy in collaboration with hospitals, municipalities, private and multinational agencies. The future direction of this research work can be extended by using IOT in communication technology for telemedicine in a disaster situation.

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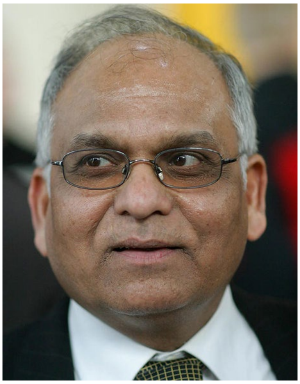

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He has been honored by the University of Rome "Tor Vergata", Italy as a Distinguished Professor of the Department of Clinical Sciences and Translational Medicine on March 15, 2016. He is Honorary Professor of University of Cape Town, South Africa, and University of KwaZulu-Natal, South Africa.

He has received Ridderkorset af Dannebrogordenen (Knight of the Dannenberg) in 2010 from the Danish Queen for the internationalization of top-class telecommunication research and education.

He has received several international awards such as: IEEE Communications Society Wireless Communications Technical Committee Recognition Award in 2003 for making contribution in the field of "Personal, Wireless and Mobile Systems and Networks", Telenor's Research Award in 2005 for impressive merits, both academic and organizational within the field of wireless and personal communication, 2014 IEEE AESS Outstanding Organizational Leadership Award for: "Organizational Leadership in developing and globalizing the CTIF (Center for TeleInFrastruktur) Research Network", and so on.

He has been Project Coordinator of several EC projects namely, MAGNET, MAGNET Beyond, eWALL and so on.

He has published more than 30 books, 1000 plus journal and conference publications, more than 15 patents, over 100 Ph.D. Graduates and larger number of Masters (over 250). Several of his students are today worldwide telecommunication leaders themselves.

Under his leadership, magnitudes of close collaborations are being established among premier universities across the globe. The collaborations are regulated by guidelines of the Memorandum of Understanding (MoU) between the collaborating universities.

He is married to Jyoti Prasad Sinha, having Master's degree in Mathematics and Business Management from India and the Netherlands, respectively. She is presently the President of Savita Holding Company in Aalborg, Denmark. They are the parents of two sons and one daughter, with five grandchildren.

The eldest is a daughter, Neeli Rashmi Prasad. She has done her Master's degree in Telecommunication from Delft University of Technology, the Netherlands and PhD from University of Rome "Tor Vergata", Italy.

She is the founding CEO of the SPA LLC, California, USA and Professor & Vice Chair of the Department of Electrical and Computer Engineering, International Technological University, San Jose, USA.

Anand Reghwa Prasad, who is the elder son, Master's & PhD from Delft University of Technology, the Netherlands. He is Chief Advanced Technologist, Executive Specialist, at NEC Corporation, Japan, where he leads the mobile communications related security activity. He is also the chairman of 3GPP SA3 (mobile communications security standardization group), a member of the governing body of Global ICT Standardisation Forum for India (GISFI), founder chairman of the Security & Privacy working group and a governing council member of Telecom Standards Development Society, India.

Their youngest son, Rajeev Ranjan Prasad has Bachelor & Master's Degree from the Netherlands and Denmark, respectively. He is an entrepreneur and is the founding CEO of a rapidly growing publishing company, the River Publishers, with head-office located in Aalborg, Denmark. River Publishers has publishing segments in various countries including USA, the Netherlands, India & several other countries.

Bhawani Shankar Chowdhry is the Dean Faculty of Electrical Electronics and Computer Engineering and former Director IICT at Mehran Univer-sity of Engineering & Technology (MUET), Jamshoro, Pak-istan. He has the honour of being one of the editor of several books Wireless Networks, Information Processing and Sys-tems, CCIS 20, Emerging Trends and Applications in In-formation Communication Technologies, CCIS 281, Wireless Sensor Networks for Developing Countries, CCIS 366, Communication Technologies, Information Security and Sustainable Development, CCIS 414, published by Springer Verlag, Germany. He has also been serving as a Guest Editor for Wireless Personal Communications which is Springer International Journal. He has produced more than dozen PhDs and supervised more than 50 MPhil/Masters Thesis in the area of ICT. His list of research publication crosses to over 60 in national and international journals, IEEE and ACM pro-ceedings. Also, he has Chaired Technical Sessions in USA, UK, China, UAE, Italy, Sweden, Finland, Switzerland, Pakistan, Denmark, and Belgium. He is member of various professional bodies including: Chairman IEEE Communication Society (COMSOC), Karachi Chapter, Region10 Asia/Paci c, Fellow IEP, Fellow IEEEP, Senior Member, IEEE Inc. (USA), SM ACM Inc. (USA).

M. R. Anjum received his Ph.D. degree from Beijing Institute of Technology, Beijing China in 2015. M.E. degree in Telecommunication and Control Engineering and BE in Electronic Engineering in 2011 and 2007 respectively from Mehran UET Jamshoro, Pakistan. Currently he is working as Assistant Professor in the Department of Electronic Engineering, Islamia University of Bahawalpur, Pakistan. He has more than 20 international conferences and journal publications. His research interest includes wireless communication. He is member of PEC, IEEEP, IEP, IJPE, UACEE, IACSIT, ICCTD, IACSIT, IAENG and reviewer of several journal and conferences.