BlackBox as a DTN device

PREETI NAGRATH
Department of Computer Science, Banasthali University, Rajasthan, India
SANDHYA ANEJA
Institute of Informatics and Communication, University of Delhi South Campus, Delhi, India
and
G.N. PUROHIT
Department of Computer Science, Banasthali University, Rajasthan, India

Disruption/Delay Tolerant Networks (DTNs) have been proposed as a solution for intermittent connectivity between two nodes that wants to communicate without having path at the time of communication. A bundle layer is added into DTN nodes to support the intermittent connectivity. The bundle layer provides storage capability within DTN nodes to store messages till intermediate node gets connected to the destination. Blackbox is used for recording, collecting and monitoring aircraft condition while in flight. Blackbox is a very important device to investigate air crash or mishappening. However, locating Blackbox may be painful effort in many cases. In this paper, we present Blackbox to work as a DTN Node in order to save efforts required for tracing Blackbox. We also discuss feasibility study of the proposal in terms of power requirement to transfer the data.

Keywords: Delay Tolerant Networks; Blackbox; Aircraft; Bundle Layer

1. INTRODUCTION

DTNs support networks where nodes are intermittently connected with each other. The intermittent connectivity is handled by a bundle layer. The Bundle layer provides persistent storage to store messages within nodes until other suitable node or destination is not found. Bundle layer allows communication among heterogeneous nodes. Store-and-forward mechanism of bundle layer makes DTN as a perfect solution for large data transfer, data transfer incurring delays and data transfer between nodes with intermittent connectivity. One of such scenarios where DTN can be helpful is to trace blackbox of aircraft if it support DTN.

Aircrafts are equipped with blackbox [Hasnain 1979; Shaji et al. 2013; Cerf et al. 2007] including two components called Flight Data Recorder [Cohen et al. 1999; Schoberg 2003] and Cockpit Voice Recorder [Ali et al. 2004]. The Flight Data Recorder and the Cockpit Voice Recorder are invaluable tools for Air Crash Investigators worldwide and plays a major role in finding out causes of aviation accidents, as well as offer plane manufacturers and government 's with considerable ideas to make air travel as safe as possible. To determine reason of aircraft crash, we need to trace the blackbox [Natanzon et al. 2012], but that tracing is a painful effort. Many times, we are not even able to locate it as it happened recently with MH370.

In this paper we propose an alternative solution that saves efforts of tracing and locating blackbox in case of aircraft crash or lost. We propose embedding DTN functionality within blackbox so that it will search another nearest DTN device and transfer the data recorded even when two are not directly connected. It can be helpful in getting the recorded data of blackbox rather than endlessly finding the blackbox in deep seas and debris. Bundle layer as a solution for intermittent connectivity converts data stored in blackbox in form of bundle and stores till data is transferred to other DTN device. Current solution needs end-to-end connectivity in order to determine the exact location. However, end-to-end connectivity is not required if DTN

Authors' address: Preeti Nagrath, G.N.Purohit, Department of Computer Science, Banasthali University, Rajasthan, India, 304022. Sandhya Aneja, Institute of Informatics and Communication, University of Delhi South Campus, Delhi, India 110021.

mechanism is embedded in the blackbox. Blackbox will be able to communicate with any other DTN-compliant device. Long range radio within blackbox will further help for long distance wireless data transfer.

As discussed in [Yanggratoke et al. 2011], we present a feasibility study of blackbox to act as DTN Node and conclude that such a device may consume around 35-45% of battery power while uploading data of around 200MB size using Wi-Fi while may consume 5-7 % battery power using wireless communication technology, XBee as power consumption rate for XBee is 1/7th fold to that of Wi-Fi.

2. RELATED WORK

In this section we present different applications where DTN has been used as a solution for data transfer in case of challenged environment. DTN [Vasilakos et al. 2011] was used in remote areas (Daknet project [Pentland et al. 2004]) to provide internet connectivity where establishing a complete infrastructure was costly. In Daknet project, all data which could not be transferred in absence of Internet in remote areas was stored on a DTN server with persistent storage in forms of bundles as per bundle protocol. DTN server transfers all data stored to mobile DTN node when mobile DTN node comes in its contact. Further, when the mobile node moves to an area where internet connectivity is available, mobile DTN node transfers data received from remote server to one internet server. Since internet server has internet connectivity so it transfers the data to respective destinations. All the nodes (DTN remote server, DTN mobile node, DTN internet server with internet connectivity) were equipped with persistent storage to store bundles till the next hop node came in contact. This is how in this application, intermittent connectivity among nodes is proposed to handle using DTN.

[Laoutaris et al. 2009] proposed DTN to be used for large data transfer. One example of large data transfer may be Large Hadron Collider (LHC). LHC produces around 27 TB of particle collision data daily that need to be pushed to storage and processing centres in other parts of world. Other example of large data transfer is Olympic Games rich media which usually need to transfer across world with different time-zones. Moreover, large video collection needs to replicate at video-on-demand servers before next day. The paper showed how DTN may be used for this application. As a part of solution, authors proposed to find out underutilize nodes within Internet for different places/time zones and to establish DTN among those underutilize nodes by providing persistent storage and including bundle layer for data transfer.

In [Lu and Fan 2010], authors presented need of DTN in battlefield. In battle fields, a solider may need to send some data to base station. However, as per battlefield scenario end-to-end connectivity to base station depends upon variety of factors like intermediate nodes resources and availability of intermediate nodes at time of request. Thus, nodes may need persistent storage to overcome intermittent connectivity till resources and conditions are streamlined for data transfer.

Space communications on interplanetary scale where long latency is measured in hours or days is also proposed as one of the application of DTN. For example, suppose two communicating nodes are on different planets. Planets moves and only periodically comes in range of each other. Thus, to transfer data, node needs to store data with persistent storage till planets of communicating nodes comes in range of each other. [Anantraman et al. 2002; Johari et al. 2015] proposed DTN in rural areas for health care data to exchange on large scale. DTN is also seen as to improve other diverse areas, including agriculture, environment, manufacturing, surveillance, and transportation [Lilien et al. 2007].

3. BLACKBOX

'BlackBox ', onboard data recorders are maintained within aircraft to capture information regarding condition of the aircraft while in flight. This recorded information may be useful in determination of causes in case some accident or malfunctioning. One component of blackbox is flight recorder and other is cockpit voice recorder. Cockpit Voice recorder records all the voice communications within cockpit while flight recorders records data from equipments positioned for monitoring throughout the journey. The Cockpit Voice Recorder records any sounds that occur within the cockpit or any communication among members of crew. The Cockpit Voice Recorder also records sounds such as engine noise, stall warnings, or emergency pings and pops. Investigators work out crucial flight information such as speed with which the plane was travelling and may pinpoint cause of a crash from the sounds the plane was making before it crashed. The Cockpit Voice Recorder is also extremely important for determining the timing of events as it contains information such as communication between the crew and ground control and other aircraft. The Cockpit Voice Recorder is usually located in the tail of a plane.

Of equal, if not more significance to the Cockpit Voice Recorder, is the Flight Data Recorder. This piece of equipment is essential to work of Air Crash Investigators as it records the many different operating functions of a plane all at once, such as the time, altitude, airspeed and direction the plane is heading. Modern Flight Data Recorders are also able to monitor number of other actions undertaken by the plane, such as the movement of individual flaps on the wings, auto-pilot and fuel gauge. Information stored in the Flight Data Recorder of a plane that has crashed is invaluable for investigators in their search for determining what caused a specific crash. [Cerf et al. 2007] proposed a wireless communication system between the blackbox and equipments used in aircraft for monitoring. The data stored on the recorders helps Air Crash Investigators generate computer video reconstructions of a flight, so that they can visualize how a plane was being handled shortly before a crash.

Moreover, each recorder is also fitted with Underwater Locator Beacon (ULB). Blackbox starts transmitting beacons as soon as recorder comes into contact with water. The range of ULB is many thousand kilometers. ULB can transmit beacons for around one month from the day of crash. These beacons when received by device in range can locate the Blackbox location. However this system fails, in case of some accident/malfunction wherein flight connection from ground gets disconnected and location of blackbox is not known upto its range. In this scenario various search operations are performed for locating the blackbox. Blackbox cant be found unless a receiver is able to make end-to-end path with it. In other words, beacons must be received by a receiver that can receive beacons. However, if Blackbox is enabled with DTN mechanism, any DTN node may receive its data even when the exact location of blackbox is not found. DTN may be modified to popup an alert if the received data is critical. Therefore, when a DTN node receives data from other DTN node in this case it will be Blackbox, the DTN receiving node will get an alert indicting received critical data to deliver immediately.

4. BUNDLE LAYER IN DTN

DTNs are network which are required to setup for applications wherein nodes in application scenario are intermittently connected. In such applications, DTNs provides a node an intelligent architecture in a sense to store data which is required to transfer. Moreover, it provides node to sense and listen other nodes in contact and furthermore decide whether to transfer data to node in contact or not.

DTN architecture extends TCP/IP layered model used for communicating devices and includes a new layer called Bundle layer into model. Figure 1 presents extended TCP/IP model for DTN including bundle layer. A bundle layer is proposed to situate between Application layer and Transport layer and includes a persistent storage for data that needs to be transferred later. Bundle layer is defined as to store a number of messages in persistent storage in form of bundles that are to be delivered together when an appropriate node comes in contact. Storing messages is important due to the fact that next hop node in the network may not be available at the time request was generated. Nodes in bundle layer uses store and forward message switching mechanism. Store and forward mechanism requires the receiving node to store messages in entirety and forward to other appropriate nodes in the network when another node comes in its contact.

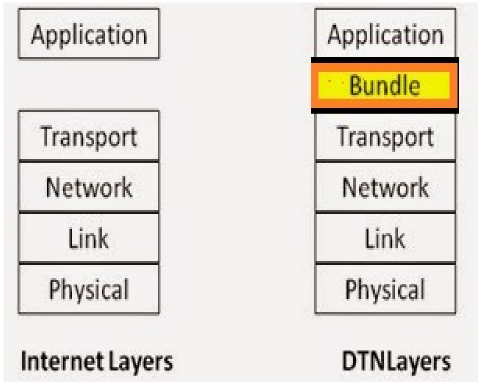


Figure. 1: Bundle Layer in DTN

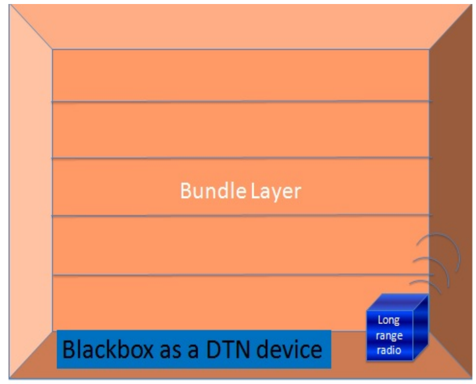


Figure. 2: BlackBox as a DTN device

Data packets called Application Data Units (ADUs) are sent from application layer to the bundle layer. Bundle layer uses bundle protocol to convert ADUs to bundles called bundle protocol data unit. A bundle protocol data unit (bundle) consists of three blocks namely Primary block, Payload block and Extension block. Primary block consists of source and destination identifiers along with other fields, Payload block consists of application data, and Extension Block is kept to extend the functionality of the Bundle Protocol. Bundle layer also allows interconnection of dissimilar nodes independently of underlying transport layers. Bundle layer defines a set of Convergence Layer Adapters (CLAs), one for each underlying transport protocol, placed on top of the Transport layer. These CLAs provide minimum set of functionality common to all nodes to successfully transmit the bundles even between nodes that are not using TCP/IP layered model.

In a way, DTN architecture provides long-term information storage, coping with disrupted or intermittent links, long delays incurred during the message transmission and communication between heterogeneous devices.

5. OUR PROPOSAL

Blackbox data is very important as it can help to identify the real cause of accident/malfunction. In some [Hasnain 1979; Monroe 1999] incidences, it was very difficult to identify the blackbox location. To find the solution of this problem, we propose blackbox as a DTN device. We propose modifications to blackbox which provides blackbox, functionality of a DTN device in addition to earlier existing functionality of data recorder. Modification may be permanent or need-based. Our proposal is to incorporate a small analyzer program, which senses sudden anomaly in air plane using continuously recorded data and generates alarm to proposed components of blackbox to start functioning as a DTN device. We propose blackbox to include two additional components to fit into it. One component of this device is radio which is capable of long range wireless communications while other component converts data stored in Blackbox in form of bundles. Wireless long range radio makes blackbox to send and receive messages wirelessly with another device at large distance and while in range of proposed equipped radio. Radio starts functioning as there is alarm by analyzer program while analyzing recorded data in blackbox. Radio starts transmitting beacons in air in case of any accident. Second component which converts data stored in blackbox in bundles also starts functioning on receiving alarm by the same analyzer program. Data stored in blackbox may be big enough. Data stored just before the accident may be more important than data stored at the beginning of flight. So, there is a need to prioritize data. Any priority mechanism may be tuned based on requirement. One default priority system may be timestamp. Based on assumption of contact duration of wireless device and blackbox to some seconds to many minutes, prioritize data is converted to bundles and stored till some wireless DTN device ready to receive is found in range.

In case of accident as analyzer program senses sudden change and generates alarm, long range radio sends beacons and waits for beacons from nearby wireless device. If beacons are received in reply, in next step, data converted and stored in form of bundles is transmitted. Whenever other wireless device owner comes to know about stored data, information may passed to destined officials. Figure 2 presents the proposed architecture with blackbox as a DTN device.

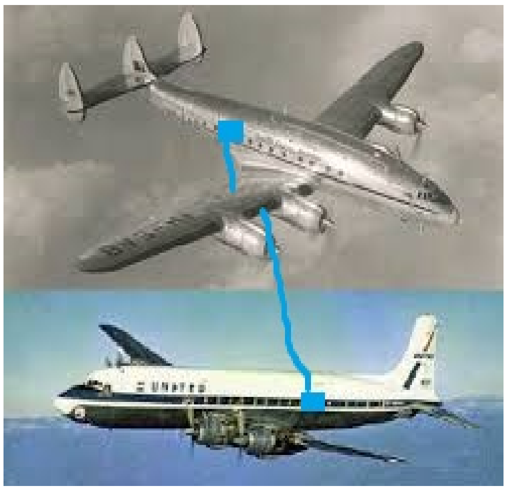


Figure. 3: Aircrafts communicating with each other as DTN devices

Figure. 4: Black Box searching for nearest DTN device for sending crucial data

One more aspect of proposal is to replicate the prioritize data with other aircrafts in the vicinity. Typically the vertical separation between aircrafts passing through same location on the way varies from one km to few kms. So, if the blackbox equipped in airplanes are DTN devices and comes in range of each other, they can exchange metadata. Exchange of metadata is good in broader terms of tracking and keeping the information replicated elsewhere may further help in case of any mishappening. Figure 3 presents scenario with the proposed communication between two aircrafts with blackbox as a DTN device while Figure 4 presents another possible scenario of accident wherein blackbox finds other DTN device on ground or under sea water or nearby to seawater on ground.

BlackBox as DTN device

In DTN Blackbox node
As the aircraft crashes, alarm is generated
BlackBox send beacons
prioritize the data
Convert the data into bundles
Receive becons from Wireless Node
if found
   send the bundles to nearest DTN device
In nearset DTN Device
Accept becons from DTN Blackbox
Accept and store prioritized data

Total battery consumption	Data uploading/ downloading	Average DTN battery consumption rate
44%	184.68MB(download)	26.20mAH/MB(download
36%	184.68MB(upload)	21.44 mAH/MB(upload)

Table I: Battery consumption for uploading and downloading data for DTN Mobile device

Characteristics	WiFi	XBee
Range	100m	1 mile
Power consumption	700mW	100mW

Table II: Comparing Wifi and XBee Characteristics

6. FEASIBILITY STUDY OF OUR PROPOSAL

Recently Flight 8501 and MH17 crashed whearas MH370 flight lost due to unknown reasons. For mentioned flights, there were possibility of communication between airplanes in vicinity and crashed/lost flights before the mishappening using blackbox as DTN device. In this section we present the feasibility of proposal for possible communication using proposed DTN. One of aspects for blackbox as DTN device include battery power consumption while sending meta data or the prioritized data recorded in flight and another aspect may be that how much time is there for possible communication after mishappening. The plane was at 32,000 to 38,000 feet (9,750 to 11,600 m) for Flight 8501 while MH370 was at altitude of 29000 feet when flights lost their connection with monitoring radar at ground. From these altitudes, it takes around 17-20 minutes [Peterson 2014; Dyment and Rowell 2012] to reach blackbox on ground. Thus, after mishappening there are 600-1000 seconds with blackbox as DTN device to search and transfer data while consuming minimum battery power.

The paper [Yanggratoke et al. 2011] presented DTN implementation for Android device which includes a DTN bundle demon service to send and receive bundles. They also discussed the results for bandwidth consumption and battery power usage while uploading and downloading data on phone whenever phone comes in contact of servers which upload and download data to it. They showed that using Wi-Fi interface (IEEE 802.11 b/g) for 3500KB bundle size, it takes around 6080 seconds to upload or download data. However, DTN bundle demon consumed 35-45% of battery power of phone while uploading or downloading data of around 200MB size. The mobile phone has 1100 mAh for 100% battery power which means 1 % battery power is equivalent 11 mAh. Energy consumption by the mobile in uploading and downloading is shown in Table I. However, in this experiment if Wi-Fi is replaced by XBee, then the comparison may be induced using Table II.

In case of any mishappening, communication component of blackbox sends beacons which last for 30 days depending on standard battery used for blackbox device. Any access communication can reduce the possibility of locating the device by reducing the period of periodic beacons transmitting time. However, the results presented by [Yanggratoke et al. 2011] shows it is feasible to transmit data as soon as blackbox comes in contact with DTN compliant device over land or under sea water location as it takes reasonable time and battery power to upload/download data. Second challenge is for long range wi-fi communication technology feasibility in airplanes. XBee has also been seen as possible solution to send real time blackbox data to locate the airplane. XBee Pro [Mahmoud 2013; Horvat et al. 2012] 50mW Series operates at 2.4GHz with a range of 1 mile [Sabeel 2013] and has a data transfer rate of 250kbps. Comparison of wi-fi and XBee characteristics from [Lee et al. 2007] is shown in table2.

Over the feasibility study, one of the aspect may be to get Internet connectivity at airplane as promised by [Medina et al. 2012], [Thanthry et al. 2005] and other satellite Internet service providers. With this it will be possible to transfer all data of blackbox in real time to authorized server at ground. However, as per current study, this service will still take time and may not be cheap very soon. Moreover, even if service providers setup their network services at large scale but it may not provide Internet connectivity over the whole flight. Due to intermittent connectivity scenario over flight, blackbox as a DTN device seems to be very promising solution even with for all forthcoming advance technologies for communications during the flight and for locating the device. As DTN nodes often idly wait for contacts and unnecessarily consume energy during these periods so an efficient solar powered nodes are suggested in paper [Doering et al. 2011].

7. CONCLUSION AND FUTURE WORK

In this paper, we proposed blackbox, a data recorder device in aircrafts as a DTN device. Locating blackbox is important in order to find exact cause of aircraft accident. This requires a lot of efforts in terms of man-power and resources. These efforts can be saved by making Blackbox a DTN compliance device.

REFERENCES

Ali, M., Bhagavathula, R., and Pendse, R. 2004. Efficient data storage mechanisms for dap. In *The 23rd Digital Avionics Systems Conference, DASC 04*. Vol. 2. 11.A.3–11.1–7 Vol.2.

Anantraman, V., Mikkelsen, T., and Ohno, L. 2002. Handheld computers for rural healthcare, experiences in a large scale implementation. In *Proceedings of development by design.*

Cerf, V., Burleigh, S.and Hooke, A., Torgerson, L.and Durst, R., Scott, K., Fall, K., and Weiss, H. 2007. Delay-tolerant networking architecture. In *http://tools.ietf.org/html/rfc4838.*

Cohen, B., Cassell, R., and Smith, A. 1999. Development of an aircraft performance risk assessment model. In *Proceedings of18th Digital Avionics Systems Conference.* Vol. 1/17 pp. vol.1. 5.A.2–1–5.A.2–8 vol.1.

Doering, M., Rottmann, S., and Wolf, L. 2011. Design and implementation of a low-power energy management module with emergency reserve for solar powered dtn-nodes. In *Proceedings of the 3rd Extreme Conference on Communication: The Amazon Expedition.* ExtremeCom '11.

Dyment, D. and Rowell, D. 2012. How to survive a plane crash.

Hasnain, S. 1979. The crash position indicator aviation safety. *IEEE*.

Horvat, G., Sostaric, D., and Zagar, D. 2012. Power consumption and rf propagation analysis on zigbee xbee modules for atpc. In *International Conference on Telecommunications and Signal Processing (TSP), IEEE.* 222–226.

Johari, R., Gupta, N., and Aneja, S. 2015. A dtn routing scheme for information connectivity of health centres in hilly state of north india. In *International Journal of Distributed Sensor Networks.*

Laoutaris, N., Smaragdakis, G., Rodriguez, P., and Sundaram, R. 2009. Delay tolerant bulk data transfers on the internet. *SIGMETRICS Perform. Eval. Rev. 37,* 1, 229–238.

Lee, J.-S., i Su, Y.-W., and Shen, C.-C. 2007. A comparative study of wireless protocols: Bluetooth, uwb, zigbee, and wi-fi. In *Industrial Electronics Society, IECON 33rd Annual Conference of the IEEE.* 46–51.

Lilien, L., Gupta, A., and Yang, Y. 2007. Opportunistic networks for emergency applications and their standard implementation framework. In *IEEE.*

Lu, Z. and Fan, J. 2010. Delay/disruption tolerant network and its application in military communications. In *International Conference on Computer Design and Applications (ICCDA).* Vol. 5. V5–231–V5–234.

Mahmoud, K. 2013. Data collection and processing from distributed system of wireless sensors. In *Masaryk University,Thesis.*

Medina, D.and Hoffmann, F., Rossetto, F., and Rokitansky, C. 2012. A geographic routing strategy for north atlantic in-flight internet access via airborne mesh networking. *IEEE/ACM Transactions on Networking 20,* 4 (Aug.), 1231–1244.

Monroe, D. 1999. Wireless transducer data capture and retrieval system for aircraft.

Natanzon, A., Winokur, A., and Bachmat, E. 2012. Black box replication: Breaking the latency limits.

Pentland, A., Fletcher, R., and Hasson, A. 2004. Daknet: rethinking connectivity in developing nations. *Computer,IEEE 37,* 1 (Jan), 78–83.

Peterson, M. L. 2014. The sigint on thirteen soviet shootdowns of u.s. reconnaissance aircraft.

Sabeel, U.and Maqbool, S. C. N. 2013. Zigbee ieee 802.15.4 standard for building automation. In *International Journal of Advanced Research in Computer Science and Software Engineering.* ISSN: 2277 128X.

Schoberg, P. R. 2003. Secure ground-based remote recording and archiving of aircraft "blackbox" data. In *http://www.dtic.mil/dtic/tr/fulltext/u2/a418284.pdf.*

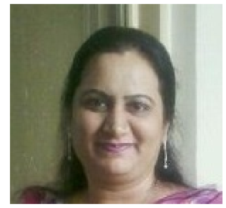
Shaji, N., Subbulakshmi, T., and Resington, M. 2013. Black box on earth - flight data recording at ground server stations. In *Fifth International Conference on Advanced Computing (ICoAC)*. 400–404.

Thanthry, N., Ali, M., and Pendse, R. 2005. Security, internet connectivity and aircraft data networks. In *39th Annual International Carnahan Conference on Security Technology, CCST '05*. 251–255.

Vasilakos, A. V., Zhang, Y., and Spyropoulos, T. 2011. *Delay Tolerant Networks: Protocols and Applications*, 1st ed. CRC Press, Inc., Boca Raton, FL, USA.

Yanggratoke, R., Azfar, A., Marval, M., and Ahmed, S. 2011. Delay tolerant network on android phones:implementation issues and performancemeasurements. *Journal of Communications 6,* 6 (sep).

Preeti Nagrath is working as an Assistant Professor in Bharati Vidya Peeth College of Engg. Delhi. Her academic qualifications include B.Tech(Computer Science),M.Tech(Computer Science).She is pursuing her Phd from Banasthali University. Her areas of interests are in routing and security in Delay Tolerant Networks and Mobile Ad-Hoc Networks. She is the member of ISTE and IEEE.



Sandhya Aneja is Assistant Professor at institute of Informatics and Communication, University of Delhi South Campus, Delhi, India. She completed her M.Tech. from IIT Delhi and PhD Computer Science from University of Delhi. Her research interests include protocol design and analysis in wireless networks with special interest in routing and security.

Prof. G. N. Purohit is a Professor in Department of Mathematics & Computing at Banasthali University (Rajasthan). He is currently Dean in Computer Science dept., Apaji Institute of Mathematics & Applied Computer Technology, Banasthali University. Before joining Banasthali University, he was Professor and Head of the Department of Mathematics, University of Rajasthan, Jaipur. He had been Chief-editor of a research journal and regular reviewer of many journals. His present interest is in O.R., Discrete Mathematics, Communication networks, Software Testing and Soft Computing. He has published more than 100 research papers in various journals and has supervised many students in these areas for Ph.D. Degree.