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Tuesday, December 14

Tuesday, December 14 11:30 - 13:00

TT1: Communication Systems

11:30 ***On the Optimal Threshold and Error Performance at Fusion Center for Diffusion-Based Molecular Communication System***

Gaurav Sharma (Indian Institute of Technology, India); Ajay Singh (Indian Institute of Technology Jammu, India)

In this paper, an analysis regarding the calculation of the threshold value and error performance of the received secondary biomarkers (Type-C molecules) at the Fusion Center (FC) in the diffusion-based molecular communication is undertaken. For this, the likelihood ratio test (LRT) has been employed for the optimal threshold value calculation at the FC. The LRT uses binary hypothesis for building substantial ground for the hard decision at the FC wherein the hypothesis H 1 corresponds to Type-C information molecules showing Log-normal distribution whereas hypothesis H 0 represents noise molecules showing Normal distribution. The plot for the optimal threshold for different time instants is also illustrated. Based on the hypothesis testing, we obtain a plot regarding the decision rule. Using, threshold analysis we then calculate the expressions for the probability of false alarm and probability of detection. Further, we calculate the error probability of the system. Numerical results show that, with increasing threshold values, the error probability decreases, which improves the system's performance.

pp. 1-6

11:45 ***RSMA for IRS Aided 6G Communication Systems: Joint Active and Passive Beamforming Design***

Aditya Jolly (Columbia University, USA); Sudip Biswas (Indian Institute of Information Technology, Guwahati, India); Keshav Singh (National Sun Yat-sen University, Kaohsiung, Taiwan)

Integrating intelligent reflecting surface (IRS) and Rate-Splitting Multiple Access (RSMA) are effective solution to improve the spectral/energy efficiency in next-generation (beyond 5G (B5G) and 6G) wireless networks. In this paper, we investigate a rate-splitting (RS)-based transmission technique for an IRS-aided communication network involving both near and cell-edge users. In particular, we derive a new architecture called IRS-RS that leverages the interplay between RS and IRS, with an aim to maximize the weighted sum-rate (WSR) of users by selecting the reflecting coefficients at the IRS and designing beamformers at the BS under the constraints of power at the base station (BS), quality of service (QoS) at each user and finite resolution at the IRS. To solve the non-convex WSR maximization problem, we propose an alternating algorithm and compare its performance with baseline non-orthogonal multiple access (NOMA) based transmission for an IRS-aided communication network for both perfect and imperfect CSIT cases. Through numerical results, it is shown that the proposed IRS-RS architecture yields better QoS with respect to the cell-edge users when compared to IRS-NOMA transmission scheme.

pp. 7-12

12:00 ***Spatial Modulation-assisted Mobile Diffusive-Drift Molecular Communications***

Sanjeev Sharma (IIT (BHU) Varanasi, India); Rangeet Mitra (University of Quebec Montreal, India); Vimal Bhatia (Indian Institute of Technology Indore, India)

Recently diffusive mobile molecular communication (MC) has emerged as a promising solution for healthcare and environmental sensing applications. In this paper, a molecular index modulation (MIM)-based mobile diffusive-drift MC system under mobility is analyzed. A non-coherent detection algorithm is formulated and results are provided for the symbol error rate (SER) and sum-rate over the diffusive-drift MC channels with/without interlink interference (ILI) and inter-symbol-interference (ISI). The results indicate that the proposed mobile MIM achieves higher sum-rate and delivers lower symbol error. Lastly, effect of various MIM system parameters are studied over MC channel-models.

pp. 13-17

12:15 ***An Investigation of the Diversity Performance of Vehicular Visible Light Communications System under Dirty Headlights, Mobility, Atmospheric Turbulence, and Different Weather Scenarios***

Pranav Sharda (Indian Institute of Technology-Delhi, India); Manav Bhatnagar (Indian Institute of Technology Delhi, India)

Over the recent few years, different studies on vehicle-to-vehicle (V2V)-visible light communications (VLC) have been reported in the literature. However, the joint impact of practical challenges such as accumulation of dirt particles or other formations on the headlights, lateral movement (mobility) of the vehicle, atmospheric turbulence, and different weather scenarios on the diversity performance of the V2V-VLC system has not been investigated yet. It is worth mentioning that the term diversity corresponds to the reliability of the communication system. To this end, in this research, we first model a comprehensive V2V-VLC system under the practical challenges of an outdoor V2V-VLC scenario. Further, we analyze the impact of these practical challenges on the diversity performance of the proposed V2V-VLC system. It is observed from the numerical results that these practical constraints have a significant impact on the diversity performance of the proposed V2V-VLC system. We consider different performance metrics such as path loss, average bit error rate, and diversity order to quantify the impact of the considered practical challenges on the proposed V2V-VLC system.

pp. 18-23

12:30 ***Analysis of Probability of Collision of CAMs in Opportunistic Vehicular Communication***

Alokojjwal Das and Dipamani Pathak (Indian Institute of Information Technology, Guwahati, India); Kukil Khanikar (Indian Institute of Information Technology Guwahati, India)

For effective implementation of intelligent transportation system (ITS) sufficient bandwidth is essential. Given the increasing trend in vehicular traffic over the years, the dedicated band allocated for vehicular communication may not be sufficient for supporting the needs of future ITS. Opportunistic use of communication bands may help mitigate the problem by making available communication bands licensed to other users for vehicular communication usage. In this paper, an opportunistic V2X (OV2X) scheme is proposed, that opportunistically opts either for C-V2X mode or an opportunistic mode which additionally uses the primary licensed band opportunistically provided the band is free to use to satisfy the requirements as much as possible. Here, by validating the model, it has been shown how the O-V2X mode enhances the performances by reducing the collision probability by an interfering vehicle. Further it is validated for a wide range of transmissions.

pp. 24-29

12:45 ***Performance of a Cooperative Full-Duplex D2D Communication in Cellular Underlay***

Suraj Parihar (IIT Delhi, India); Kamal Agrawal (Indian Institute of Technology Delhi, India); Pratik Chakraborty (Indian Institute of Information Technology Kalyani, India); Shankar Prakriya (Indian Institute of Technology, Delhi, India)

This paper investigates the performance of a non-orthogonal multiple access (NOMA) enabled full-duplex (FD) device-to-device (D2D) communication network that is underlaid in the cellular uplink. The uplink cellular user is licensed to serve the BS. For improving spectrum utilization efficiency, it also concurrently relays D2D information in FD mode. The transmit powers of D2D nodes are chosen such that the cumulative interference at the BS is below the Interference Temperature Limit (ITL). Using the statistical channel knowledge and successive interference cancellation at the D2D nodes, an expression for the D2D throughput is derived in closed-form. Thereafter, using the approximate throughput expressions, a closed-form expression of ITL apportioning parameter is derived in closed form that maximizes the D2D throughput while ensuring desired quality of service at the BS. Computer simulations demonstrate accuracy of the derived expressions.

pp. 30-35

TT2: 5G Networks

11:30 ***Efficient Service Allocation Scheduling Algorithms for 5G User Equipments in Slice-in-Slice Networks***

Sharvari Ravindran (International Institute of Information Technology Bangalore, India); Saptarshi Chaudhuri and Jyotsna Bapat (International Institute of Information Technology, India); Debabrata Das (International Institute of Information Technology - Bangalore, India)

In 5G, network slicing is a prominent feature to provide end-to-end Quality of Experience (QoE) for specific user equipment (UE) requirements. A key technology that facilitates the enhancement of network slicing performance is Open-Radio Access Network (ORAN). The support of network slicing is an ongoing technical effort in ORAN. This paves the way for implementing challenging and predictive system control strategies to serve several UEs, leveraging UE specific aggregated data, medium access control (MAC) key performance indicators for optimizing per-UE QoE, service allocation and resource scheduling. In this paper, to improve system performance at a granular level, we propose a novel concept of formation of multiple optimized UE service specific slice-in-slice categories across network slices. There have been no clear state-of-the-art that have addressed the relationships and supportability of UEs of different services across slice-in-slice categories during service allocation in network slicing. In this paper, we propose novel Service Allocation Scheduling (SAS) algorithms for UEs services. Novel multi-objective multi-constraint optimization models are formulated to achieve improved service level guarantees. A graph theoretical optimum service allocation strategy is proposed for UE services to maximize the network slice capacity. A probabilistic system resource prediction algorithm for UE services conditioned on previously occurred services is further proposed. Finally, we compared our proposed SAS with state-of-the-art service scheduling algorithms, where SAS ensures 5.12 and 6.22 times throughput gains.

pp. 36-41

11:45 ***Method for Optimal Resource Allocation during RRC Connection Establishment in 5GNR***

Isha Maheshwari (Samsung R&D Institute-India, Bangalore, India); Raju Gupta (Samsung R&D Institute India - Bangalore, India)

In 5G/NR, the purpose of Radio Resource Control (RRC) Connection Establishment procedure is to transit User Equipment (UE) from RRC_IDLE or RRC_INACTIVE state to RRC_CONNECTED state involving establishment of Signaling Radio Bearer-1 (SRB1). As a part of RRC Connection Establishment, UE mostly performs Contention Based Random Access (CBRA) procedure for accessing serving cell. However due to

certain scenarios (discussed in subsequent sections of paper) which can occur in real field deployments, the problematic situation may arise due to which UE may not be listening to gNodeB (gNB) scheduling during RRC establishment leading to significant wastage of radio resources. These resources would have been utilized for other users connected in the cell. This paper addresses those issue scenarios at gNB followed by a framework to avoid the resource wastage at Medium access Control (MAC) which is exemplary and can be easily implemented. Additionally, this paper proposes the optimization of internal processing at the higher layers by clearing the UE context in above said cases. Finally, we evaluate the proposed framework in terms of the accuracy by estimating resource saving and latency reduction in clearing UE context.

pp. 42-47

12:00 ***Resolving Coverage and Interference conflicts in 5G***

A. R. Ashok Kumar (Rashtreeya Vidyalaya College of Engineering, India); Harsha Hoovinalli (Cisco Systems, India); Girish Rao Salanke N S (Rashtreeya Vidyalaya College of Engineering, India)

With 5G targeting to achieve faster connectivity speeds, ultra low latencies and a greater bandwidth, complexities associated with 5G have also increased. 5G achieved the stated objectives through unification of many technology advancements. These include - network densification, variety of node types, separation of control plane and data plane, use of multiple frequency bands and frequency reuse and many others. This resulted in sheer increase in complexity of the system and thus increase in capital expenditure (CAPEX) and operational expenditures (OPEX). Efforts are in place to reduce the OPEX by automating network functionalities such as configurations, optimization and healing. Self Organizing Networks (SON) are the one introduced to do this. SONs are defined to work for a specific independent objective. When these SONS operate concurrently in the network, they may result in parametric and/or objective based conflicts. Thus, there is a need to develop framework which reduces these conflicts by enabling SON functions to develop end to end network behavior intelligence. In this paper, a framework that resolves conflicts between two such SONs - Inter Cell Interference Coordination (ICIC) and Capacity and Coverage Optimization (CCO) is proposed. Both the SONs, CCO and ICIC have contradicting objectives, one to increase the coverage and other to reduce the interference respectively. Further, both these SONs depend upon the transmission power of Base Station (BS) and Evolved NodeB (eNB). Thus, aim is to determine optimal transmission power for eNBs that reduces conflicts between coverage and interference. The approach used is to determine optimal transmission power based on past operational data. As its hard to have any past operational data, following three steps procedure is followed to determine optimal transmission power for eNBs. 1) Through simulation, data set is build by collecting the data towards interference and coverage by varying transmission powers of eNBs 2) Using the data set prepared in Step1, optimal transmission parameters are estimated using machine learning model 3) eNBs are powered with transmission power values estimated in Step2 and network behavior is observed for possible conflicts between two SONs. Its observed that newly determine transmission powers for eNB significantly reduce conflicts between two SONs. This work demonstrated use of data science as a way to resolve conflicts between SONs.

pp. 48-53

12:15 ***5G Networks for Industrial Applications: the Ecosystem of NPNs***

Gabor Soos (Budapest University of Technology and Economics & Magyar Telekom Nyrt, Hungary); Daniel Ficzere (Budapest University of Technology and Economics, Hungary); Roberto Padovani (Marposs S.p.A., Italy); Attila Frankó (Budapest University of Technology and Economics, Hungary); Sándor Veress (T-Systems Hungary, Hungary); Pál Varga (Budapest University of Technology and Economics, Hungary)

One of the well-known target areas of 5G network services is industrial manufacturing itself. There are comprehensive standards and further research available for industrial manufacturing solution integration, but these are only partially known in the Business-to-Business context. Various traditional use cases have shown the capabilities of 5G as a data transfer technology; moreover, the industry's adoption of 5G is only getting started. One of the most feasible options could be the Non-Public Network (NPN), also known as Campus: a 5G private network, implemented on the basis of individual requirements -- Service Level Agreements (SLAs) -- of its customers. This paper provides an overview for system integrators as well as business stakeholders about the benefits of 5G NPNs as a long-term investment in contrast to other, more traditional technologies. Moreover, key players and their main interactions in the 5G industrial economy are discussed as well.

pp. 54-59

12:30 ***OCTANE: A Joint Computation Offloading and Resource Allocation Scheme for MEC Assisted 5G NR Vehicular Networks***

Veerendra Kumar Gautam (IIT Hyderabad, India); Chinmay Tompe (NYU Tandon School of Engineering, USA); Bheemarjuna Reddy Tamma (IIT Hyderabad, India); Antony Franklin A (Indian Institute of Technology Hyderabad, India)

New vehicular applications like Augmented Reality (AR), Virtual Reality (VR), and High Definition Map (HD Map) have computational intensive and latency-sensitive traits and require collaboration among nearby vehicles. Computational offloading is used to improve the accuracy and performance of these applications, as it allows computational jobs to be processed on MEC servers at the cell edge. Here, the challenge is how to effectively take offloading decisions at the MEC server by considering wireless transmission delay and computational delay in the presence of time varying channel conditions due to vehicular mobility. In this work, we aim to maximize the number of jobs offloaded to the MEC server under application's deadline constraints while ensuring fairness among vehicles. First, we formulate the computational offloading as an integer linear programming (ILP) problem where both the transmission delay of 5G NR and MEC computational resources are taken into account. Then, we propose an online heuristic for joint computational offloading and resource allocation, OCTANE, that jointly takes 5G NR radio resources and computational resources into consideration while taking offloading decisions. Further, to provide fairness among vehicles, Transport Block Size (TBS) based Medium Access Layer (MAC) strategy is proposed for allocation of TDMA symbols in the 5G NR uplink. Finally, extensive simulations are performed in the NS-3 5G NR module with mobility traces taken from SUMO using OpenStreetMap to evaluate OCTANE and ILP model. Simulation results show that the proposed OCTANE scheme performs better than a state- of-the-art solution and is close to the ILP model in terms of offloading success rate.

pp. 60-65

12:45 ***Energy Efficient On/Off Switching of mmRSUs for 5G Vehicular Networks***

Moyukh Laha (IIT Kharagpur, India); Raja Datta (Indian Institute of Technology Kharagpur, India)

The next-generation vehicular network applications require complex data processing along with reliable and fast message transfers. The LTE macro base stations and WAVE technology cannot support such a high data rate and ultra low latency communication. 5G RSUs equipped with mmWave beams (mmRSUs) along with the edge computing techniques are capable of supporting such service demands. However, for energy efficiency, the ON time of such mmRSUs needs to be minimized. It is possible to support the target service demand by intelligently switching the mmRSUs ON/OFF based on the current traffic conditions. We formulate the optimal switching of mmRSUs as an Integer Linear Program and propose a greedy method solution to this NP-Hard problem. Performance validation in a city with real data shows that our proposed

scheme significantly reduces the energy consumption of the deployed 5G mmRSUs and decreases misuse of network resources.

pp. 66-71

TT3: Wireless Networks

11:30 ***A Novel Load Estimation Based Dynamic CBAP Allocation Policy for mmWave WLANs***

Pavana Ravi Sai Kiran Malyala (Indian Institute of Technology Jodhpur, India); P Rajalakshmi (Indian Institute of Technology Hyderabad, India)

The new millimeter-wave (mmWave) wireless local area network (WLAN) standards such as IEEE 802.11ad and IEEE 802.11ay utilize the spectrum from 57 to 71 GHz to offer high data rates. However, at such high frequencies, the channel conditions are adverse, thus reducing the communication range. Hence, both the access point (AP) and stations (STAs) use high-gain directional beamforming with the entire coverage area around the AP divided into virtual antenna sectors. The STAs communicate with the AP by contending for the channel during the allocated contention-based access periods (CBAPs) to the sector in which it is residing. However, the AP uniformly allocates the CBAPs for every sector, reducing channel utilization if the traffic generation across the sectors is non-uniform. In this paper, we exploit the drawbacks of uniform CBAP allocation and propose a new load estimation-based dynamic CBAP allocation policy to improve channel utilization under non-uniform traffic regimes across the sectors. Also, we develop a novel and accurate analytical model for analyzing the performance of different CBAP allocation policies. The analysis shows that the proposed allocation policy improves the overall network throughput by 17% and reduces the packet overflow ratio by 54% on average compared to the uniform allocation policy.

pp. 72-77

11:45 ***Hybrid BLE/LTE/Wi-Fi/LoRa Switching Scheme for UAV-Assisted Wireless Networks***

Wilson Ayyanthole Nelson, Sreenivasa Reddy Yeduri and Ajit Jha (University of Agder, Norway); Abhinav Kumar (Indian Institute of Technology Hyderabad, India); Linga Reddy Cenkeramaddi (University of Agder, Norway)

The unmanned aerial vehicles are deployed in multiple layers to monitor an area and report the information to the ground control station. When we use a single communication protocol such as Bluetooth Low Energy (BLE)/Wi-Fi with low range, the data has to pass through multiple hops for data transfer. This, in turn, increases the delay for data transmission. Even though LoRa protocol supports longer distances, the delay is more due to the limited bandwidth. Thus, in this work, we propose a hybrid BLE/LTE/Wi-Fi/LoRa switching scheme that consumes lower energy in addition to reducing the average delay in the network. The proposed scheme switches between the communication technologies based on the lower energy consumption. The performance of the proposed hybrid switching scheme is compared with the individual communication protocols in terms of both energy consumption and average delay. Through extensive numerical results, we show that the proposed hybrid switching scheme performs better in comparison to the individual communication technologies.

pp. 78-83

12:00 ***Reinforcement Learning for Admission Control in Wireless Virtual Network Embedding***

Haitham Afifi (Hasso-Plattner-Institut, Germany); Fabian Jakob Sauer (Paderborn University, Germany); Holger Karl (Hasso Plattner Institute & University of Potsdam, Germany)

Using Service Function Chaining (SFC) in wireless networks became popular in many domains like networking and multimedia. It relies on allocating network resources to incoming SFCs requests, via a Virtual Network Embedding (VNE) algorithm, so that it optimizes the performance of the SFC. When the load of incoming requests -- competing for the limited network resources -- increases, it becomes challenging to decide which requests should be admitted and which one should be rejected.

In this work, we propose a deep Reinforcement learning (RL) solution that can learn the admission policy for different dependencies, such as the service lifetime and the priority of incoming requests. We compare the deep RL solution to a first-come-first-serve baseline that admits a request whenever there are available resources. We show that deep RL outperforms the baseline and provides higher acceptance rate with low rejections even when there are enough resources.

pp. 84-89

12:15 ***Centralized vs Decentralized Resource Analysis of Green FiWi Networks***

Kinshu Kumar and Akshita Gupta (Indraprastha Institute of Information Technology, India); Vivek A Bohara (Indraprastha Institute of Information Technology, Delhi (IIIT-Delhi), India); Anand Srivastava (Indraprastha Institute of Information Technology Delhi, India)

Fiber Wireless (FiWi) networks have recently emerged as one of the preferred solutions for high-speed internet as they provide large capacity, high stability, and user mobility. This paper considers a real-time campus wireless local area network (WLAN) deployment scenario. The resource allocation framework to power the FiWi network components such as optical network units (ONUs) and access points (APs) is analyzed. Specifically, an off-grid scenario is considered wherein the ONU and AP collectively called 'ONU-AP' is powered through photovoltaic (PV) panels and batteries. We propose a three step iterative algorithm (TSIA) to compute the minimum resource requirement of the ONU-AP. A comparative analysis of resource requirements for two network setups is presented, namely, a) decentralized setup- where each remotely located ONU-AP has its own power source and b) centralized setup- where the ONU-APs are powered by the centralized power unit. The results presented show that the centralized power setup for the FiWi network is more power-efficient compared to the decentralized setup. Furthermore, a carbon footprint analysis to compare the carbon dioxide (CO_2) emissions for the centralized and decentralized setups is also presented in the paper.

pp. 90-95

12:30 ***Deep-Learning Based Modulation Identification in Wireless Communication System***

Saurabh Jaiswal (Indian Institute of Technology Patna, India); Pushp Paritosh (SRM-IST, Main Campus, Chennai, India); Preetam Kumar (Indian Institute of Technology Patna, India)

This paper studies the performance of deep learning (DL) for the identification of analog and digital modulation in orthogonal frequency-division multiplexing (OFDM) based wireless communication systems. OFDM is the key enabling technology for 4G and going to be part of 5G communication system implementation. The conventional methods for signal modulation identification (SMI) are discrete wavelet transform (DWT), adaptive wavelet transform (AWT) and, mixed parameters. These are based on statistical models and therefore encounter the bottleneck of accuracy. To handle this problem, machine learning (ML) algorithms were proposed which uses support vector machine (SVM), k nearest neighbors (KNN), decision tree (DT), etc. However, the feature extraction has to be done manually which makes these methods very difficult to implement in practical OFDM systems. Therefore many DL based SMI methods are proposed which handles the limitations of the mathematical models by making use of the availability of large datasets. In this paper, we have used a Convolutional Neural Network (CNN) for identification of

both analog and digital modulation in 4G/5G wireless system. This proposed deep learning based method achieves accuracy higher than 95% which is better than the traditional methods.

pp. 96-101

12:45 ***A Contact-Based Classification to Aid Routing in Heterogeneous Wireless Networks***

Sara El Alaoui (Purdue University, USA); Byrav Ramamurthy (University of Nebraska-Lincoln, USA)

The emergence of the Internet of Things (IoT), Internet of Everything (IoE), and now Tactile Internet (TI) among other new networking paradigms, has been enabled by the architectural changes of the Internet through 5G, 6G and beyond. New network architectures had to be heterogeneous in order to fulfill the tighter requirements for latency, reliability, adaptability, etc, the seamless support for a variety of devices, protocols and applications led to the creation of the multi-layered network architectures that include Non Terrestrial Networks (NTN). Many research questions remain open and routing is one that is especially challenging. One manifestation of this heterogeneity is the diversity of spatio-temporal contacts established for communication between different network entities both inter- and intra-layer. In this paper, we expand the definition of heterogeneous wireless networks. We then propose a novel and rigorous mathematical model for contact classification that captures several aspects of heterogeneity. Finally, we provide real-world application examples and map them to our proposed classification.

pp. 102-107

W1: Workshop W1: Fog Networks: The Next Generation Cellular Communication Systems

11:30 ***Fog-compute capable smart metering infrastructure***

Vineet Kandunuri (San Diego State University, USA); Mahasweta Sarkar (San Diego State University & Center for Neurotechnology, USA); Christopher Paolini (San Diego State University, USA)

We present an open-source fog-computing architecture for LoRaWAN\textregistered-based smart grid advanced metering infrastructure. The presented device is designed to monitor and measure local consumer power demand and perform real-time load-shedding decisions at the network edge. The presented metering device measures the (I*{RMS}), (V*{RMS}), apparent, reactive, and active power of an attached load and transmits these measurements to a LoRaWAN\textregistered\ Gateway and then an application server using the MQTT protocol. The fog-computing architecture is designed to locally predict the time and distance between generations of outages during a cascading power outage. Cascading power outages can inflict devastating consequences on the economic and operational security of city infrastructure, and can even result in fatalities. Should a localized failure occur, the fog network reacts to mitigate failure propagation by shedding load in a structured way to reduce consumer loss by powering off load in priority order. The proposed fog-computing architecture will benefit Smart Cities by providing a means by which energy companies can selectively shed power at the edge of a grid by powering off customer appliances in order of increasing criticality, thereby mitigating the propagation of a failure and reducing consumer costs that result from power loss. Our micro-controller code and PCB board design files have been made publicly available in GitHub for the community to use as a reference architecture.

pp. 108-112

Wednesday, December 15 11:30 - 13:00

TT4: Security-I

11:30 ***P4Filter: A two level defensive mechanism against attacks in SDN using P4***

Ananya Saxena, Ritvik Muttreja and Shivam Upadhyay (IIIT Naya Raipur, India); K Shiv Kumar (IIT Hyderabad, India); Venkanna U. (IIIt Naya Raipur, India)

The advancements in networking technologies have led to a new paradigm of controlling networks, with data plane programmability as a basis. This facility opens up many advantages, such as flexibility in packet processing and better network management, which leads to better security in the network. However, the current literature lacks network security solutions concerning authentication and preventing unauthorized access. In this work, our goal is to avoid attacks in a two level defense mechanism (P4Filter). The first level is a dynamic firewall logic, which blocks packets generated from an unauthorized source. The second level is an authentication mechanism based on dynamic port knocking. The two security levels were tested in a virtual environment with P4 based switches. The packets arriving at the switch from unknown hosts are sent to the controller. The controller maintains an ACL using which it assigns rules for both the levels to allow or drop the packets. For port knocking a new random sequence is generated for every new host. Hosts can only connect using the correct sequence assigned to them. The tests conducted show this approach performs better than the previous P4 based firewall approaches due to two security levels. Moreover, it is successful in mitigating specific security attacks by blocking unauthorized access to the network.

pp. 113-118

11:52 ***Addressing ICS Security Challenges using Simplex Architecture***

Sahil Bhandary Karnoor and Prahadheeswaran Mathiyazhagan (Indian Institute of Science, India); Haresh Dagale (IISc, India); Chandramani Singh (Indian Institute of Science, India)

Safety-critical services managed by Industrial Control Systems (ICS) are now far more exposed to external threats. Security frameworks that ensure that the physical systems are fail-safe when compromised due to unforeseen vulnerabilities such as zero-day exploits are desired. We survey security challenges and mitigation strategies used for protecting ICS. We explore different types of vulnerabilities and elucidate how they have been exploited in the past. We identify key ICS attributes that differentiate them from traditional IT systems deployed in enterprise networks. Further, we show how these attributes can be used by designing a security framework based on Simplex Architecture. We evaluate this framework on an ICS testbed and demonstrate its effectiveness in ensuring the safety of the physical process system even under external attacks.

pp. 119-124

12:15 ***Online Network Attack Detection using Statistical Features***

Ritesh Ratti and Sukumar Nandi (Indian Institute of Technology Guwahati, India); Sanasam Ranbir Singh (IIT Guwahati, India)

In recent years, several supervised intrusion detection systems have been proposed. However, these methods require labeled data for training and cannot automatically adapt to frequently changing network

traffic scenarios. It is also required for data to be updated periodically and requires the model to be retrained to detect new attacks. This emphasizes the need for the development of unsupervised detection systems that can target zero-day attacks. In this paper, we propose an unsupervised solution that relies on detecting attacks in a discrete-time sliding window using the distance between statistical features. The proposed algorithm utilizes generated cluster profiles and estimates the distance between statistical features to trigger an attack event if it exceeds the predefined threshold. The proposed method was applied to CICIDS-2018 dataset and tested for FTP Brute Force and HTTP Distributed Denial of Service attacks.

pp. 125-130

12:37 ***Predicting Potentially Undetectable Flows in DPI System using Machine Learning***

Ankan Saha (Samsung Research Institute, Bangalore, India); S Varun (SRIB, India); Uday Trivedi (Samsung R&D Institute, Bangalore, India)

A Deep Packet Inspection (DPI) system examines packet payload to identify traffic flow. For flows that are detected, DPI system processes average 1 to 2 packets while for eventually undetected flows, DPI system processes 10+ packets on average before concluding that detection is not possible. For such flows, maximum packet processing is done without any eventual detection result. Our proposed algorithm adds intelligence in DPI system to predict that given flow has very low chance of eventually being detected by given DPI system. With that, DPI engine can stop processing that flow after few packets and save lot of unnecessary processing to enhance DPI throughput. Our initial results show that a competitively fast solution achieving around 98% accuracy can be derived using Machine Learning techniques.

pp. 131-136

TT5: Security-II

11:30 ***Email Validation & Arbitration Framework and Platform based on Blockchain for Legal Matters***

Rushya Sree Reddy Butukuri, Sravya Atche and Gourinath Banda (Indian Institute of Technology Indore, India)

Electronic mail (email or e-mail) is a method of exchanging messages between people using electronic devices. Such email communication has become the default mode of messaging for business and personal uses. E-mail is a form of documentary evidence that, like all other types of documentary evidence, may be admitted as an evidence in the court. However, the reliability and authenticity of email as an evidence, like that of other types of evidence, will be scrutinized against tampering. In this paper, we propose a solution that makes possible to accept emails as reliable, trustworthy and authentic documents that can be accepted as evidence in the court of law. We design and detail a third-party email validation arbitration service that guarantees the trust and reliability of emails by offering a way to resolve conflicts.

pp. 137-142

12:00 ***DES Based IDS for detection Minimal De-authentication DoS Attack in 802.11 Wi-Fi Networks***

Mayank Agarwal (Indian Institute of Technology Patna, India)

The inherent security weaknesses of 802.11 MAC Access Layer is the primary reason for a wide variety of attacks that can be mounted on 802.11 Wi-Fi networks. In this paper we focus on Minimal De-authentication (de-auth henceforth) DoS Attack which is a low rate de-auth DoS attack in Wi-Fi networks. There exist studies which can tackle flooding based de-auth DoS, however, there has been limited work done in the

case for minimal de-auth DoS attack. The network frame exchange under minimal de-auth DoS attack and normal de-auth process is the same, making the detection even more challenging. Since minimal de-auth DoS attack involves sending only a few spoofed de-auth frames into the network, no significant frame injection can be observed in the network. So the contemporary signature and anomaly based Intrusion Detection System (IDS) fail to recognize the minimal de- auth DoS attack. In this paper, we propose a Discrete Event System (DES) based IDS for detecting minimal de-auth DoS attack. The proposed DES based IDS provides a novel detection method and does not require any protocol changes, or require any server/client side changes and can be proved for completeness and correctness. Experiments results show that the proposed DES based IDS detects minimal de-auth DoS attack swiftly and with high accuracy.

pp. 143-148

12:30 ***Enabling Fog Computing based Dynamic Security Service Function Chaining for 5G IoT***

Vashish N. Imrith (University of Mauritius, Mauritius); Pasika S Ranaweera (University College Dublin, Ireland & University of Ruhuna, Sri Lanka); Sneha Damree (University of Mauritius, Mauritius); Madhusanka Liyanage (University College Dublin, Ireland & University of Oulu, Finland)

Fog computing is an edge computing strategy which fuels adaptation of Internet of Things (IoT) in many domains. The decentralized and dynamically deployable features of the fog nodes are useful to satisfy the service requisites of IoT nodes. However, security is a prime concern for both fog, and IoT deployments; where their inhibited limited resources are expanding the threat landscape for the malicious adversaries towards resource exhaustive attempts. Despite the available security servicing tools being effective, a singular service is not adequate to address all the intricacies of the contrived threat landscape. Hence, the requirement of multiple security services to operate in a cooperative domain is an obvious fact. However, integrating multiple security services in a resource constrained fog node is a challenge. Thus, in this research, we are leveraging Service Function Chaining (SFC) concept as a method to deploy multiple security services/ tools in a resource constrained edge node (i.e. Raspberry Pi), while evaluating its adaptability in a developed experimental virtual platform. The implemented SFC strategy on the fog node is compared with a resourceful virtual machine to understand the performance issues.

pp. 149-154

Wednesday, December 15 11:30 - 17:30

WiE: Women in Engineering

11:30 ***A Prediction-based Online Cost Optimization Algorithm for 5G Vertical***

Jyoti Tiwari (Indian Institute of Technology, Hyderabad, India); Shashwat Kumar (Indian Institute of Technology Hyderabad, India & Swinburne University of Technology, Melbourne, Australia); Antony Franklin A (Indian Institute of Technology Hyderabad, India)

In 5G, end-to-end network slicing enables new business models and use cases across all industry verticals. Network slicing is an efficient solution that addresses the diverse requirements of businesses characterized by a Service Level Agreement (SLA). 5G service providers offer the network slices through multiple plans differentiating in leasing period, resources, and price. For businesses, it is very challenging to select a cost-effective plan to support the traffic with uncertain future demand. In this work, we propose a prediction-based online algorithm that minimizes the cost through plan selection for different applications in industry

verticals. First, the future traffic demand is predicted using the Recurrent Neural Network (RNN) based Long Short-Term Memory (LSTM) model, which continuously learns and adapts to the dynamic requirement and achieves higher prediction accuracy. The traffic prediction provides insights into future demand, which the proposed algorithm uses for the plan selection decision. We also formulate the problem as an Integer Linear Program (ILP), which provides the problem's optimal offline solution. Results from extensive simulations with real-world datasets illustrate that the proposed algorithm reduces the best worst-case expected Competitive Ratio (CR) by 20% over randomized ski-rental algorithm and 37% over deterministic algorithm.

pp. 155-160

11:57 ***Efficient Seed Selection for IC-IS Multiphase Diffusion Model***

Kalyanee Devi (Indian Institute of Information Technology, Guwahati, India); Rohit Tripathi (Indian Institute of Information Technology Guwahati, India)

The increased availability of high speed internet and social networking websites such as Twitter, Facebook, etc. has made people more highly connected. Many topics of interest such as news, rumor, etc. quickly spread in an online social network. This paper proposes a new information propagation model named IC-IS Model where the seed nodes are selected in multiple phases and diffusion is triggered in each phase with a predefined time gap between successive phases. In this model, active nodes in one phase can return to an inactive state in the successive phases during the diffusion process. This model represents a diffusion phenomenon where diffusion is initially increasing up to a certain time phase and then the diffusion spread attains almost a steady state. This paper also proposes a Degbet seed selection scheme to address the challenge of selecting the best users that can activate the maximum number of nodes within a limited budget. A comparative analysis is performed to study the influence spread of seed nodes selected from the different centrality based seed nodes selection schemes and the proposed Degbet scheme under the IC-IS model. The analysis is performed over three different real-world datasets.

pp. 161-166

12:25 ***Routing and Scheduling of Key Assignment in Optical Networks secured by Quantum Key Distribution***

Purva Sharma (Indian Institute of Technology, Indore, India); Vimal Bhatia (Indian Institute of Technology Indore, India); Shashi Prakash (Devi Ahilya University, India)

Quantum key distribution (QKD) has potential of providing long-term security as it is based on the fundamental principles of quantum mechanics. Security of information transmitted through optical networks has attracted attention recently due to its vulnerability to attacks post quantum computers. Hence, the integration of QKD into optical networks can significantly improve the security of existing and future optical networks. In QKD-secured optical networks, the quantum channel and the classical channel are integrated into a single optical fiber to reduce the deployment cost of the network infrastructure. However, due to limited network resources in a single optical fiber, the efficient provisioning of network resources (wavelengths and time slots) and blocking are two major issues in such networks. In this work, a resource assignment strategy with scheduling, namely, resource assignment with scheduling (RA-WS) has been proposed for utilization of network resources efficiently. In the RA-WS strategy, the QKD lightpath requests (QLPRs) have been served according to the proposed scheduling criterion. Moreover, the proposed scheduling criterion for routing, wavelength and time-slot assignment (RWTA) can reduce the effect of QLPRs blocking because of the limited network resources. The performance of the proposed RA-WS strategy has been analyzed in terms of blocking probability (BP), success probability of update secret key (SP USK), and time-slot utilization ratio (TSUR) with different reserved wavelengths for quantum signal channel (QSCh), i.e., W Q and different time slots (n tr). Simulations performed on NSFNET

network topology indicate that the RA-WS strategy performs better than the baseline strategy, i.e., resource assignment without scheduling (RA-WOS) in terms of all the considered metrics.

pp. 167-172

12:53 ***On the Performance of Hovering UAV-Based FSO Communication System***

Deepshikha Singh (IIT Indore, India); Swaminathan Ramabadran (Indian Institute of Technology Indore, India)

Unmanned-aerial-vehicle (UAV)-based communications have recently gained popularity due to their line of sight (LoS) nature, dynamic, and cost effective deployment as compared to fixed infrastructures. Further, the consistent requirement of higher data rates for next-generation networks has encouraged the development of free space optics (FSO) communication. Due to the cost effective, license-free, LoS, and high bandwidth nature of FSO links, they are especially used for UAV-to-UAV connectivity. In this paper, we investigate the performance of a hovering UAV-based FSO communication system. The channel model takes into account the effect of four major impairments namely atmospheric path loss, atmospheric turbulence, non-zero boresight pointing errors, and angle-of-arrival (AoA) fluctuations. We derive the closed-form expressions for outage probability and average symbol error rate (SER) considering both heterodyne detection (HD) and intensity modulation/direct detection (IM/DD) techniques for UAV-to-UAV link over the generalized Malaga distribution. In addition, the asymptotic analysis is also carried out to obtain the asymptotic bounds and diversity gain of the system.

pp. 173-178

13:20 ***Synchronization in Power-Efficient DST-based ACO-OFDM-VLC Systems***

Suseela Vappangi (VIT Andhra Pradesh, India); Venkata Mani Vakamulla (National Institute of Technology Warangal, India)

In the recent times, Visible Light Communication (VLC) has evolved as a new communication standard due to its stunning notability to render ubiquitous connectivity by emerging as a prominent revolutionary to radio frequency (RF) based wireless communications. However, an orthogonal frequency division multiplexing (OFDM) based VLC system is susceptible to timing errors. Therefore, this work addresses the synchronization aspects in asymmetrically clipped optical OFDM (ACO-OFDM) system which is exploiting real trigonometric transform like discrete sine transform (DST). The striking notability is that without the necessity of Hermitian Symmetry criteria, this optical OFDM system takes the advantages of real signal processing transformation technique like DST. Thus, this technique reinforces the transmission of double the data symbols in comparison to conventional optical OFDM system which is based on standard Fourier signal processing. Besides, this work derives the elaborate mathematical expressions illustrating the deleterious effects of unreliable timing errors in DST-based ACOOFDM system. In addition, this paper interprets as well as compares the performance of timing synchronization algorithms exploiting the periodicity property of the optical OFDM symbol with the training symbol based STO estimation algorithm in DST-based ACO-OFDM system. Moreover, this work validates the derived Cramer Rao Lower Bound (CRLB) and the simulated results infer that derived CRLB pertaining to the timing errors contributes the minimum mean square error (MSE) when compared with other STO estimation algorithms.

pp. 179-184

13:48 ***Secrecy Rate Maximization at Near User in Untrusted NOMA with Trusted DF Relay***

Insha Amin (Indian Institute of Technology, Jammu, India); Deepak Mishra (University of New South Wales (UNSW) Sydney, Australia); Ravikant Saini (Indian Institute of Technology Jammu, India); Virendra Singh (Indian Institute of Technology Bombay, India)

In this paper, we consider a cooperative non- orthogonal multiple access (NOMA) system with two untrusted users and a trusted decode-and-forward (DF) relay. We formulate two optimization problems to maximize the secrecy rate of near user under two scenarios, namely joint and individual power budget constraints on source and relay. Closed-form expressions are obtained for power sharing between source and relay, along with energy-efficient power allocation coefficients for both the users. Numerical results are provided, which verify the exactness of the theoretical analysis and present insights on the design of a secure cooperative communication network.

pp. 185-190

14:16 ***Joint Power Allocation and User-pairing in Multi-beam Hybrid Satellite Terrestrial Networks***

Jayati Dutta (Indian Institute of Technology Hyderabad, India); Sumit Chakravarty (Kennesaw State, USA)

In recent 5G era, the demand of high data rate is increased several times than that of 4G LTE system. Not only the high demand for data throughput but also massive connectivity is one of the most important features of 5G communication systems. The rapid increase of users creates pressure on the terrestrial network. Besides this, some remote places on earth are not connected to communication systems. To connect those remote (sub-urban and rural) areas to the main communication system and to provide a higher data rate to the users, Multi-beam High Throughput Satellite (HTS) system is used. One of the main features of HTS is its multiple narrow spot beams where the transmission signal is concentrated in a small region. But the main challenge is handling these advance features using the limited resources (limited transmission power and frequency band). One of the important constraints for the HTS system is the limited transmission power. To connect more users with this limited transmission power Non-Orthogonal Multiple Access (NOMA) techniques can be used as it is proposed as a very useful solution of sharing the resources and massive connectivity. Another constraint is the limited frequency band, so the HTS system has adopted 2 or 4-color frequency reuse techniques, but to increase more data rate 1-color frequency reuse or full frequency reused technique can be used. These frequency reuses can cause strong interference like inter-beam interference, co-channel interference, and this interference can cause degradation of the SINR which leads to the poor data rate of the system. In this paper, the strong inter-beam interference due to full frequency reuse is managed using Co-operative NOMA at beam level, where the most dominating interference from neighboring beams can be used as co-operating signals. The HTS systems operate in the Ka-band (26.5 GHz - 40 GHz) and there are also Femtocell, microcell in the heterogeneous terrestrial network which causes mm-Wavelength (28 GHz - 38 GHz). These phenomena can cause interference from terrestrial networks to the users of the satellite system. Due to this terrestrial interference (which follows the path loss model), the users of any beam can experience different normalized channel gain, and depending on their channel gain, NOMA can also be applied to those beam-edge ground users. The beam-edge users experience inter-beam interferences and terrestrial interference with different magnitude. While applying NOMA to those users, the users can be paired depending on their normalized channel gain. The user that has less terrestrial interference is the strong user while the user with more terrestrial interference is the weak user. One strong user is paired with a weak user and the Successive Interference Cancellation (SIC) technique can be applied (as the strong and weak users have different normalized channel gain) to separate their superimposed signal. The data rate of each beam is defined by the total data rate of the user-pair and it is assumed here that the total time frame is divided into some sub-time-slots and only one user-pair is activated within a particular sub-time-slot. We have proposed a problem formulation considering all the constraints and developed an algorithm for user-pairing as well as an algorithm for obtaining data rate in each beam using optimal transmission power allocation. In this paper, comparative studies on Spectral Efficiency Vs Normalized transmission power and data-rate in each beam are done and the results of

our proposed scheme are compared with the paper "Interference management using co-operative NOMA in multi-beam satellite systems" (ICC 2018). Our paper depicts how to serve the beam-edge users who experience strong interference as well as how to increase the connectivity along with increasing the data-rate in a particular beam.

pp. 191-196

14:43 ***Maximal Ratio Sparse Vector Coding for Short Packet Transmission***

Astha Awasthi (National Institute of Technology, Meghalaya & Meghalaya, India); Mithun Kumar Kumar (NIT Meghalaya, India); Shravan Kumar Bandari (National Institute of Technology Meghalaya, India); Venkata Mani Vakamulla (National Institute of Technology Warangal, India)

With the proliferation of automated services in recent years, the demand for reliable communication among the devices and machine-human interactions has increased like never before. In general, the amount of information that is exchanged for mission-critical applications is tiny for service categories such as ultra reliable and low latency communication (URLLC) and massive machine-type communications (mMTC). To handle short packet transmission, sparse vector coding (SVC) was recently proposed where the packet information is embedded into the positions of the sparse vector. In this paper, to further improve the performance of SVC in terms of reliability, maximal ratio transmission (MRT) is employed. The distinctive feature of the proposed scheme to that of conventional SVC is that the composite of weighted MRT coefficients with sparse vector is transmitted over the channel. Simulated results under realistic international telecommunication union (ITU) channel models suggest that by exploiting spatial diversity at the transmitter side, the block error rate (BLER) can be reduced with the increased number of antennas. In brief, MRT-aided SVC transmission can be a key enabler for reliable communication and a practical choice for beyond 5G (B5G) communication systems.

pp. 197-200

15:11 ***Optimal User Pairing using the Shortest Path Algorithm***

Kanchana Katta and Ramesh Ch Mishra (Indian Institute of Information Technology Senapati, Manipur, India); Kuntal Deka (IIT Guwahati, India)

In power domain non-orthogonal multiple access, user pairing is based on a distance difference between users as well as power allocation. When the distance difference between the users becomes small, the interference caused by users can affect the system performance. Therefore, it is very important to implement an efficient pairing algorithm in NOMA systems to maintain a minimum distance and pair with the shortest path among the users available in the same cell. In this paper, we have proposed the shortest path algorithm for user pairing which separates the strong and weak users in order to promote massive connectivity. This algorithm performs better for the weak users when we compare it to the conventional Hungarian Algorithm in terms of user capacity. Further, results show that the proposed method achieves an average BER performance is similar to the Hungarian algorithm-based scheme but with much lower complexity.

pp. 201-206

15:39 ***IB-RPL: Embedding Isolation and Blacklisting of Malicious Nodes in RPL for Securing IoT-LLNs***

Rashmi Sahay (The ICFAI Foundation for Higher Education, Hyderabad, India); Geethakumari G (BITS-Pilani, Hyderabad Campus, India); Barsha Mitra (BITS Pilani, Hyderabad Campus, India)

The constrained characteristics of devices in the Internet of Things (IoT) environment deters the implementation of robust security solutions. Consequently, intrusion of malicious nodes in IoT environment

is a frequent phenomenon. Such malicious nodes often exploit the vulnerabilities of the underlying routing protocol to instigate several DDoS attacks. The IPv6 Routing Protocol for Low Power and Lossy Networks (RPL), popularly used in numerous IoT applications, is susceptible to several routing attacks. Various researchers have proposed mechanisms for detecting routing attacks and identifying malicious nodes in RPL-based IoT environments. However, the benefit of such mechanisms can only be harness when identified malicious nodes are quickly isolated from the IoT environment. Therefore, the removal of identified malicious nodes outweighs any other security measure. Malicious nodes, often located in remote locations, are difficult to dislodge at the earliest. This paper proposes to embed the isolation and blacklisting mechanism of suspected malicious nodes in the routing process itself. We propose upgrades in the existing RPL routing process to enable fair nodes to collaboratively weed out malicious nodes and restrict the spread of malicious activities in the IoT environment. We call the modified RPL with self mechanized isolation and blacklisting of malicious nodes as IB-RPL.

pp. 207-212

16:07 ***Hybrid Intrusion Detection System using an Unsupervised method for Anomaly-based Detection***

Saumya Bhadauria (ABV-IIITM Gwalior, India); Tamanna Mohanty (ABV-IIITM GWALIOR, India)

With the advancement of network technologies, new threats and attacks have started to gain space. These have put the safety of the network at stake. These threats and attacks could be significantly detected by a Network Intrusion Detection System (NIDS). The existing NIDS makes use of classical ML algorithms that fail to detect new attacks. This happens because the traditional systems are often built on selection-based intrusion detection techniques which only detect the attacks for which they are trained for. Another intrusion detection technique is anomaly-based detection which is capable of detecting new attacks if an unsupervised method is used. But this system suffers from high false-positive rates. Hence, this work proposes such a hybrid system where a combination of signature-based detection algorithm(Decision Tree, Naive Bayes, or its variants) with an unsupervised (clustered) anomaly-based detection algorithm (DBSCAN or Isolation Forest) is used to detect both studied as well as novel attacks. The proposed work is aimed to improve the detection rate and lowering the false alarm rate.

pp. 213-218

16:34 ***Intellectual Property Protection using Blockchain and Digital Watermarking***

Saumya Bhadauria (ABV-IIITM Gwalior, India); Pranjal Kumar (ABV-Indian Institute of Information Technology and Management, Gwalior, India); Tamanna Mohanty (ABV-IIITM GWALIOR, India)

Most of the digital systems completely ignore the generation of the watermark and how the watermark will be stored, while developing strong watermarking algorithms to avoid the unauthorized replication of the same asset. In this paper, a framework scheme based on digital watermarking using blockchain technology is proposed for protecting the digital assets of Intellectual Property. Blockchain is used to store the transaction details and the watermark information helps us track the asset's ownership transfer and provides authentication of the watermark. This work demonstrates an implementation of the light and efficient functions, i.e., image hashing using the Wavelet hash function, storing hashed information of the owner and the digital assets using a Quick Response Code, and enables watermarked image storage using the IPFS. We demonstrate that the blockchain can also be used to record the transfer of the asset from one owner to another. One of the takeaways from this proposal is that the elimination of the third-party results in fewer data and copyright leaks which in turn makes the system more reliable and secure. In fact, it speeds up the process of the ownership transfer of the assets.

pp. 219-224

17:02 ***Blockchain-inspired Distributed Trust in a Smart Vehicular Network System***

Tripti Samal and Rudra Dutta (North Carolina State University, USA)

A smart vehicular network aims at goals of safe operation, and aggregate efficiency, by sharing information between cars, so that traffic information observed by some cars can be used by others out of observation range. However, as is common in multi-agent complex IoT systems, the priorities and intents of the various vehicles are distinct, such as different desired speed, or in contesting rights of way. This leads to a need for security, specifically, establishing a trust in the data generated by vehicles. This security need to be operative at the network level because the individual device security is expensive and not practical.

We propose using a blockchain-inspired solution for achieving distributed trust in the data generated in a multi-agent system. We design and implement a discrete-event vehicular network simulator, and demonstrate how it achieves an all-to-all trust when the network is connected, by using just the time and location of generation of a message or data. We conduct simulation experiments to evaluate the impact of using blockchain on network latency of this resource-constrained IoT system.

pp. 225-230

Wednesday, December 15 14:00 - 15:30

W7: Workshop 7: 5G & Future Wireless Technologies (5G-FWT 2021)

14:00 ***DECT-2020 New Radio System Level Assessment for Multi-Hop Assisted mMTC usage Scenario***

Tanmay Singhwi (The LNMIIT, India); Samya Andra and Sai Jaswanth Seelam (Shiv Nadar University, India); Rahul Makkar (The LNM Institute of Information Technology Jaipur, India); Divyang Rawal (LNMIIT, India); Nikhil Sharma (The LNM Institute of Information Technology, Jaipur, India)

All the candidate technologies submitted to the ITU-R are expected to meet the minimum performance requirements for getting recommended as IMT-2020. 3rd generation partnership project (3GPP) is one of among that submitted the technologies to ITU-R. This paper considered a submission for digital enhanced cordless telecommunication new radio (DECT-2020 NR) technology evaluation. We proposed various approaches for relay selection, channel/frequency allocation for the relay and device association with relays for massive machine type communication (mMTC) scenario based on DECT-2020 NR specifications. These approaches are compared based on SINR received by the users. Simulation results conclude that the angles based approach is the most optimal method for relay selection and device association. For an average percentile of users, a difference of 7dB can be observed between the worst and best approach.

pp. 231-236

14:22 ***Ultra-Dense 5G Network Deployment Strategy: A Reinforcement Learning Approach***

Biswapratap Singh Sahoo (Nokia Networks, India & National Taiwan University, India); Prerit Jain, Dheeraj Kumar and Satya Kumar Vankayala (Samsung R&D Institute Bangalore, India)

The millimeter-wave (mmWave) bands signal comes with high attenuation, and it is prone to blockage by almost all solid materials. To overcome the harsh propagation conditions, the fifth-generation (5G)

mmWave networks demand dense deployment of nodes; however, that may be infeasible because of the unavailability of fiber drops everywhere to provide wired backhauling. The introduction of Integrated Access and Backhaul (IAB) enables rapid and cost-effective mmWave ultra-dense network deployments through self-backhauling in the same spectrum. As the network deployment cost and backhaul connectivity become prohibitive, the operator needs economically viable solutions. This paper presents a two-fold solution based on approximation and reinforcement learning to reduce deployment costs while providing network stability and performance. In particular, we minimize the number of fiber-connected nodes in terms of hop-constraint, considering blockage and channel conditions in the network. Furthermore, we provide comprehensive experimental results and give insights based on the simulation results.

pp. 237-241

14:45 ***SDN Based Mobile Data Offloading Scheme Using LTE and WiFi Networks***

Santhosh Kamath (Madav nagar, India); Sanjay Singh and M. Sathish Kumar (Manipal Institute of Technology, India)

The exponential growth of the smartphone and new applications are significant challenges for the network provider to maintain the user's QoS. With the availability of multiple radio interfaces in the smartphone, simultaneous data transmission on both LTE and WiFi gained attention for cost-effective data offloading, which aggregates the spectrum from both LTE and WiFi called Heterogeneous network (HetNet). To further explore the benefits of data offloading in HetNet, we propose a multipath-based algorithm to maintain a minimum data rate for a given application. Accurately modeling and predicting wireless channel quality variations is essential for many networking applications such as scheduling and improved video streaming over LTE networks. We also consider the effect of channel quality by using LSTM considering Received signal strength indicator (RSSI) as a parameter in maintaining minimum required throughput of video application. We take advantage of Software-Defined Networking (SDN) in the data offloading scheme for multipath in LTE-WiFi integrated network. The performance is compared with the state-of-the-art method for average throughput, and overall 78\% improved result in overall throughput is observed using our approach.

pp. 242-247

15:07 ***Sparse Dense Neural Network Architecture for Turbo Decoding in Cloud Systems***

Satya Kumar Vankayala (Samsung R&D Institute Bangalore, India); Swaraj Kumar (Samsung R&D Institute, India); Thirumulanathan D (Indian Institute of Technology, Kanpur, India); Seungil Yoon (Samsung Electronics, Korea (South)); Issaac Kommineni (Samsung R&D Institute India-Bangalore, India); Lakshmi Narayana V S Ch (Samsung R&D Institute, Banglore, India)

The process of decoding data in communication systems is among the most computationally expensive processes. As we move towards cloud based architectures, there is a need for faster data decoding. We propose a novel Sparse Dense Neural Network (SDNN) solution for the turbo decoder module. We show that our proposed solution outperforms both the conventional decoders and the other ML-based decoding algorithms in the literature, in terms of computational complexity. Specifically, a computational gain of about (10\%) to (20\%) is achieved, with the BER performance kept comparable to ML-based state-of-the-art turbo decoders. We then show that our solution is also scalable with the order of modulations scheme.

pp. 248-253

Thursday, December 16 11:30 - 13:00

TT6: Cryptography

11:30 ***Construction of 4 x 4 MDS Matrices for Lightweight Block Ciphers***

Vikas Tiwari (CR RAO AIMSCS UOH CAMPUS HYDERABAD TELANGANA INDIA, India); Swamy Naidu Allu (CR Rao Advanced Institute of Mathematics Statistics and Computer Science, India); Ajeet Singh (CR RAO AIMSCS UOH CAMPUS HYDERABAD TELANGANA INDIA, India); Ashutosh Saxena (Infosys Technologies Limited, India)

Diffusion is one of the fundamental property while designing block ciphers. Diffusion layer is derived by a linear diffusion matrix that transforms an input vector to output vectors through diffusion operations. For a block cipher to resist from linear and differential attacks, it is indispensable to strengthen the diffusion power of the matrix. Maximizing the branch number is certainly helpful to obtain the stronger security requirements along with the better computational performance. The matrix having maximum branch number is an ideal and most suitable diffusion layer. We call this matrix as Maximal Distance Separable (MDS) matrix. MDS matrices are important constituent for block ciphers and are widely used in various ciphers such as AES [1], LED [2], SKINNY [3] etc. It is essential to reduce the computational complexity and implementation costs while designing the diffusion layer. This paper presents an algorithm to construct 4 x 4 dimension matrices. Utilization of some specific structure of matrices and minimal XOR counts construct these matrices as lightweight in nature. The practical adaptability and optimality of the proposed approach is also discussed through various experimental evaluations.

pp. 254-259

11:52 ***Performance Evaluation of ANU block cipher on 8-bit AVR for IoT node security***

Swapnil A Sutar (Acharya Nagarjuna University, India & C. R. Rao Advanced Institute of Mathematics Statistics & Computer Science, India); Priyanka Mekala (C. R. Rao AIMSCS)

Recent advancement in IoT with next-generation wireless systems produces a data security challenge due to bulky encryption standards which are not capable to provide efficient hardware performance on tiny and low-end IoT devices. Numerous lightweight ciphers are proposed to address data security in constrained IoT environments. It is essential to evaluate the hardware performance of these designed ciphers which are proved their robustness against various cryptanalysis techniques. This paper implements and analyses the new block cipher ANU on tiny and low-end devices with the aim of secured IoT node development. Additionally, we implement popular block cipher PRESENT which was designed with consideration of constrained IoT applications such as Radio Frequency Identification (RFID). Finally, we compare our achieved results of ANU with PRESENT performance metrics including flash memory, code size, machine cycle, and execution time. Both designs are evaluated and analyzed on an 8-bit µ-controller (AVR ATmega32) simulation platform.

pp. 260-265

12:15 ***Inviolable e-Question paper via QR code Watermarking and Visual Cryptography***

Aniket Agrawal (Indian Institute of Technology Bhubaneswar, India); Kamalakanta Sethi (Birla Global University, India & Indian Institute of Technology Bhubaneswar, India); Padmalochan Bera (IIT

Bhubaneswar, India)

Recurrent claims of electronic question paper (e-QP) leakage and examination malpractices in educational institutions can be resolved via secured transfer of the combination (X) of Run Length Encoding (RLE) for binarized diagrams and question text of the tamper-resistant e-QP, by the course faculty (F) to the trusted collector (C). For this, n Quick Response (QR) code image shares are generated by F through (n, n) Visual Cryptography (VC) and partially modified through binary array generated via initialization of the secret key known to F and C. This happens for 2 halves of the secret e-QP image. Digital watermarking is being used to embed the n modified QR code shares for 1 e-QP chunk in the same for the 2nd chunk and submitted to n non-trusted parties P_1, P2*, ..., P*{n-1} and P_n which deliver their respective portions to C before the examination to avoid attracting the adversary's attention. C superimposes the n party shares, extracts the watermarked QR code for the first part from that for the other e-QP part, scans them to get 2 X vectors whose original state can be restored through the same binary array, and the image RLE is used for decompression in order to get the final e-QP. The benefit of utilizing QR codes for watermarks is that they feature error correction through reconstruction, high decoding reliability, and large data capacity.

pp. 266-271

12:37 ***Data Deduplication Scheme with Multiple Key Servers in Public Clouds***

Bhautik Gosai (DA-IICT, India); Manik Lal Das (DAIICT, India)

Data storage in clouds and data access from clouds have become routine activities by individuals as well as corporate because of ease of accessibility, availability, shareability and low-cost storage facility provided by the cloud service providers. While seeing multiple advantages in cloud storage, data duplication has been seen a concern in terms of data ownership, data redundancy, and data quality. Data deduplication mechanism not only minimizes the concern, but also gains customer confidence in storing/providing authentic data in cloud storage, which also achieves better storage space efficiently in the clouds. Data deduplication mechanism becomes easy when data are stored in plaintext, but challenging when data are stored in an encrypted form. In this paper, a scheme with strong tag consistency is proposed that can address data deduplication in storage of encrypted data. The proposed scheme performs tag based deduplication at the file levels with a non-interactive self-generation deduplication decision tree based on randomized tagging files. The scheme provides strong tag consistency and identifies fake file upload attack.

pp. 272-277

TT7: Cellular Networks

11:30 ***Optimal Coverage-Aware Hovering UAV Height***

Poonam Lohan (Punjab Engineering College Chandigarh, India); Deepak Mishra (University of New South Wales (UNSW) Sydney, Australia); Neena Gupta (PEC University of Technology, India)

In this paper, a low complexity solution method is proposed to find the optimal height of a hovering unmanned aerial vehicle acting as wireless base station (UAV-BS) to maximize the average coverage probability to ground users in a given coverage field. In contrast to existing literature, where the optimal height solution has been defined numerically using exhaustive search without providing any closed form expression of coverage probability, we provide analytical depth to provide closed form expression for tight approximation of coverage probability and to find the optimal altitude of UAV-BS with less complexity. Numerical and simulation results confirm the optimal UAV-BS height in terms of coverage probability and reduction in complexity to find the optimal altitude solution.

pp. 278-283

11:45 ***A Cooperative Federated Learning Mechanism for Collision Avoidance using Cellular and 802.11p based Radios Opportunistically***

Suhel Sajjan Magdum (IIT Hyderabad, India); Antony Franklin A (Indian Institute of Technology Hyderabad, India); Bheemarjuna Reddy Tamma (IIT Hyderabad, India)

Reinforcement learning (RL) is a powerful learning framework which can be used in complex environments such as autonomous driving. Generally, in autonomous driving, vehicles run RL algorithm locally. However doing so will not give a desirable performance as each vehicle will only consider its own environment. So in autonomous driving it is very important that the vehicles make actions with the knowledge learned by other vehicles as well which can be received using V2X technology. However, relying on a single radio or V2X mode of communication is not desirable. In the absence of communication infrastructure on the road side, one can depend on technologies such as 4G/5G for V2N (Vehicle-to-Network) communication and Wi-Fi Direct for V2V (Vehicle-to-Vehicle) communication. Vehicles can depend on cellular technologies for indirect mode of communication (V2N), if direct V2V communication is not possible with other vehicles present in the close vicinity. To reap in the benefits of both Federated learning and V2X, we present a federated learning architecture with support from V2X, where all the participant agents make their actions with the knowledge received using V2X, even when they are acting in very different environments. Effectiveness of the proposed V2X federated learning system is demonstrated using collision avoidance application using Flow, Veins and SUMO. Simulation results suggest that it important to use a federated learning to significantly improve the reliability of of the collision avoidance application.

pp. 284-289

12:00 ***Adaptive Sparse Aware Algorithm based Channel Estimation for mmWave Hybrid MIMO System***

Vidya Bhasker Shukla (IIT Indore, India); Rangeet Mitra (ETS Montreal, Canada); Vimal Bhatia (Indian Institute of Technology Indore, India)

Millimeter-wave (mmWave) MIMO has emerged as a promising technology that offers improved spectral efficiency and enhanced data rates for 5G and beyond 5G (B5G) wireless networks. However, the achievement of this high spectral efficiency and high data-rates is subject to accurate channel-estimation, which in-general, is challenging for mmWave MIMO due to scattering and blockages. These factors lead to inherent sparsity in mmWave MIMO channel, which in-turn necessitates sparse-aware channel-estimation methods. Therefore, this paper proposes a zero-attracting least mean squares (ZA-LMS) based channel-estimator and analyzes its convergence. The proposed ZA-LMS based channel-estimator exploits the inherent sparsity of the overall channel-matrix, that in-turn, leads to significantly faster convergence. These benefits of the proposed sparse channel-estimation algorithm and its convergence are illustrated through computer simulations over typical mmWave MIMO channel.

pp. 290-295

12:15 ***Performance of an Adaptive Cooperative NOMA Scheme with Transmit Antenna Selection***

Amrita Mukherjee (National Institute of Technology Durgapur, India); Pratik Chakraborty (Indian Institute of Information Technology Kalyani, India); Shankar Prakriya (Indian Institute of Technology, Delhi, India); Ashis Kumar Mal (NIT Durgapur, India)

In this paper, we investigate the performance of hybrid cooperative non-orthogonal multiple access (CNOMA) underlaid in a primary network. The CNOMA setup consists of a secondary near user (NU), provisioned to act as a full-duplex (FD) relay for a secondary far user (FU). We propose a novel mode

switching mechanism, where the NU can choose to operate in either of the following two modes: 1) The Cooperative Mode (CM) and 2) The Non-Cooperative Mode (NCM). It is only when the NU achieves a desired performance of its own, it chooses to operate in CM, while it switches to NCM otherwise. Through this intelligent switching between modes, the NU retains the same performance as in a network without the FU. We employ a maximum received-power based transmit antenna selection (MRP-TAS) strategy and derive analytical expressions for the outage probability at the NU and FU under peak transmit power and peak interference power constraints. The interference temperature limit (ITL) imposed by the primary network is carefully apportioned between the secondary transmitter and the NU with an ITL apportioning parameter (ITLAP). An optimum choice of both ITLAP and NOMA power allocation parameter (NPAP) is proposed in closed-form, that results in minimum outage performance. The analytical results are validated by extensive simulation studies, and superiority of the proposed scheme over conventional NOMA and OMA schemes is established.

pp. 296-301

12:30 ***Compressive Sensing based Low Complexity Terahertz Receiver***

Vaishali Sharma and Vimal Bhatia (Indian Institute of Technology Indore, India); Sanjeev Sharma (IIT (BHU) Varanasi, India)

Terahertz (THz) communication is recognized as a promising technology that could help meet the growing demand of wireless system for the forthcoming 6G wireless technology. However, sampling rate required for signal processing in the THz system is very high and difficult to realize in practical systems. To combat this need for sampling at THz rates, the THz signal detection and demodulation at sub-Nyquist rate is carried out at the receiver. In this paper, we propose a signal-matched (SM) measurement matrix for THz system for sub-Nyquist rate sampling. The proposed SM matrix senses signal containing higher energy more efficiently as compared with the commonly used Gaussian and discrete cosine transform (DCT) matrices in the compressed sensing (CS) framework. Theoretical analysis and simulation results show that the bit error rate (BER) performance of a CS-based THz receiver utilizing the proposed SM measurement matrix is better than the popular Gaussian and DCT measurement matrices, and is close to a conventional system sampled at Nyquist rate albeit with much lower system complexity.

pp. 302-306

12:45 ***Comparative Study on Error in MIMO Radar DOA Estimation***

Tata V Srinivasa Rao and Lakshi Roy (National Institute of Technology, Rourkela, India);
KamalaKanta Mahapatra (National Institute of Technology Rourkela, India)

Hardware implementation for faster real-time signal processing in multiple-input multiple-output (MIMO) radar beamforming, estimation of direction of arrival (DOA) using multiple signal classification (MUSIC) is attractive. The above subspace-based method works with a basic principle of eigenvalue decomposition and is found suitable for application-specific integrated circuit (ASIC), field-programmable gate array (FPGA). In that regard, the cyclic Jacobi method is used for computing eigenvalues and eigenvectors, by orthonormal plane rotations in accomplishing eigenvalue decomposition. However, the fasterness and foremost, the accuracy of the DOA estimator realized in such above hardware depend on the involved number of antenna elements in an array, the number of snapshots, and the signal-to-noise ratio. Therefore, the comparative study on DOA estimation error in MUSIC and QR-based algorithms is presented in this paper.

pp. 307-312

TT8: Internet of Things

11:30 ***Adaptive Distributed Queuing Random Access Protocol for LoRa based IoT Networks***

Devpriya Kanojia and Vinod Kumar Jain (PDPM Indian Institute of Information Technology, Design and Manufacturing Jabalpur, India)

The Internet of Things is the idea of connecting any device to the Internet and to other connected devices. There are several wireless communication technologies in IoT depending upon the area in which they are employed. For device simplicity, Low Power Wide Area Network (LPWAN) tend to use a simple channel access control protocol such as Aloha, which impacts performance. While several LPWAN technologies are available in the field of IoT, focus on the Long Range (LoRa) network is still ongoing. Distributed Queuing LoRa (DQ-LoRa) algorithm has been used in the MAC layer of LoRa with fixed number of slots in its contention window for improving the performance of LoRaWAN. Depending upon the number of slots, either maximum throughput or minimum energy consumption could be achieved. The proposed work namely Adaptive DQ-LoRa (ADQ-LoRa) hovers over the dynamic slots mechanism for channel access control protocol in conjugation with the physical layer of LoRa. With every frame, the number of slots change depending upon the collisions and idle slots in the previous frame. With respect to DQ-LoRa protocol, which has the best performance, ADQ-LoRa gives 22% reduction in average delay and increases throughput by 12.5%. It has been shown to work better when nodes are more than 2000 in number, resulting in 4% decrease in energy consumption.

pp. 313-318

11:52 ***Fault-Tolerant Concurrent Data collection Trees for Industrial IoT Applications***

Arvind Kumar and Rakesh Matam (Indian Institute of Information Technology Guwahati, India); Somanath Tripathy (IIT Patna, India)

Industrial Internet of things (IIoT) refers to a network of industrial devices, equipped with a multitude of sensors that are connected to the Internet. The data generated by these devices can be accessed by multiple applications simultaneously necessitating concurrent data-collection. With shared device infrastructure and devices being power-constrained, the probability of device failures due to battery exhaustion is high, thus resulting in partitioned network topology and impacting data collection. Furthermore, the network-topology reconstruction process is also energy-consuming. In this paper, we propose a fault-tolerant concurrent data collection process. We show through simulations how the proposed algorithm handles device failures without affecting the overall data-collection time.

pp. 319-324

12:15 ***Experimental evaluation of power saving mode against powering down in an NB-IoT modem***

Prashanth Lingala (Indian Institute of Technology Hyderabad, India & Honeywell, India); SaiDhiraj Amuru and Kiran Kuchi (IIT Hyderabad, India)

Narrowband Internet of Things (NB-IoT) is standardized by 3GPP to support low power devices that are deployed in locations that mandate requirements such as deep coverage and long battery life. This technology is adopted in applications such as smart water and gas metering, agriculture and many that require infrequent access to NB-IoT network. In such applications, the devices are in deep sleep more than 95% of the time. In deep sleep, the modems are expected to consume near zero currents. In order to support such applications 3GPP introduced power saving mode (PSM). During this deep sleep devices are not reachable for any downlink communication. Some NB-IoT modems such as one from Quectel provide an option to power down the modem, henceforth called as power down mode (PDM). This option looks more

attractive as the modem consumes less current compared to PSM. This paper experimentally evaluates PDM and PSM using a Quectel modem. It is observed that even though current consumption in PDM is less than PSM for more than 95% of the time, still PSM is better than PDM when looked at holistically, i.e, cumulative of active, idle and sleep current consumption. Additionally, PDM generates additional signalling compared to PSM.

pp. 325-330

12:37 ***Location based detection mechanism for PUEA on CR enabled 5G-IoT network***

Avinash Reddy Avuthu (MNIT, Jaipur, India); Arunima Sharma (India); Dinesh Gopalani (MNIT Jaipur, India); Ramesh Babu Battula (Malaviya National Institute of Technology Jaipur, India)

The investigation and the location of conceivable network attacks are fundamental for wireless networks, specifically for mobile cognitive radio networks, because of their qualities like dynamic spectrum allocation and constant frequency hopping. Cognitive radio (CR) enabled 5G Massive machine-type communications (mMTC) is a prominent solution to establish efficient connectivity among millions of devices. The primary user emulation attack (PUEA) is possibly the main attack in cognitive radio since it dangers the cognitive cycle. Due to opportunistic spectrum access, the malicious secondary user (SU) tries to exploit the spectrum access by mimicking the spectral characteristics of a primary user (PU). The mimicking of PU spectrum signal causes spectrum inefficiency that degrades the network performance. In this paper, we propose two approaches to detect the emulation attackers in a given CR-enabled 5G-IoT network. In the first approach, each SU shared its location information with only legitimate SUs. The transmitter is localized based on the received signal strength and known location coordinates of these receivers. In the second approach, the received signal energy vectors from the primary transmitter and malicious nodes are stored in the database. The adversary is detected based on the closeness of the newly received energy vector and the stored energy vectors in the database. The simulation results demonstrated that the proposed method outperforms the existing PUE mechanism.

pp. 331-336

Thursday, December 16 14:00 - 15:30

TT10: Spectrum and Channels in Cellular Networks

14:00 ***Detection for Spectrum Sensing in CRN Under Impact of Distributional Uncertainty of Noise and Interference***

Madhukar Mohanrao Deshmukh (KL University, India); Albena Mihovska and Ramjee Prasad (Aarhus University, Denmark)

Since the advent of Cognitive Radio and exploitation of unused spectrum by secondary devices, spectrum has gained immense importance. In cognitive radio network setting, due to very low received signal to noise ratio (SNR), spectrum sensing has been a challenging task. Further, signal detection is obscured due to presence of accumulated interference for which the statistical distribution is unknown and has significant distributional uncertainty. Covariance based signal detection methods have been proposed by various authors and proved to be better than other methods due to its independence on SNR, accuracy, and medium algorithmic complexity. Some results from Random Matrix Theory (RMT) on modelling of covariance matrices can be used in signal detection. This paper presents an algorithm for detection of

Chi-Square distributed independent random signals using Wishart matrix which model the covariance matrix. A centering matrix is employed to scale the sample covariance matrix with Wishart distribution. The signals under various fading environment are used to evaluate the performance of the proposed algorithm. Also, a DVBT-2K signal is used to evaluate the performance for more realistic conditions. Furthermore, quantification of distributional uncertainty of accumulated interference in DTV based CRN is calculated using differential entropy of pdf of the interference. The quantified uncertainty is used to calculate the new threshold for detection. As per our knowledge, it is observed in the proposed work that the Maximum-Minimum Eigenvalue (MME) based proposed algorithm performs better than other proposed schemes in terms of probability of detection and complexity.

pp. 337-342

14:15 ***A Robust Adaptive Algorithm using Inverse Square Root Cost Function for Underwater Channel Estimation***

Bishnu Prasad Mishra and Annet Wilson (National Institute of Technology Goa, India); Trilochan Panigrahi (National Institute of Technology, Goa, India); Samrat Sabat (University of Hyderabad, India)

Channel estimation in underwater acoustic (UWA) communication is challenging due to the presence of impulsive noise, extreme multipath spread, and the time-varying nature of the environment. In an impulsive environment, gradient-based algorithms based on the error square cost function fails. Maximum correntropy criteria (MCC), logarithmic cost (LCLMA), and sigmoidal cost functions are used to minimize the effect of impulsive noise with an added cost of convergence rate and complexity. This paper presents a robust cost function, namely Inverse Square Root (ISR), to mitigate the above issue. The slope of the ISR cost function is negligible for high impulsive noise. We compare the effectiveness of the ISR cost function with state-of-the-art cost functions by varying the impulsive noise probability in the UWA channel. In comparison to MCC and LCLMA algorithms, the simulation results show that ISR cost function-based learning converges faster in the presence of higher percentage of impulsive noise with less computing complexity.

pp. 343-347

14:30 ***Performance Evaluation of Conventional Spectrum-Allocation Policies for C+L Band Elastic Optical Networks***

Rana K. Jana (Indraprastha Institute of Information Technology, New Delhi, India); Bijoy Chand Chatterjee (South Asian University, India); Abhishek P. Singh (Indraprastha Institute of Information Technology, New Delhi, India); Anand Srivastava (Indraprastha Institute of Information Technology Delhi, India); Biswanath Mukherjee (University of California, Davis, USA); Andrew Lord (British Telecom, United Kingdom (Great Britain)); Abhijit Mitra (IIIT-Delhi, India)

Multiband elastic optical network (MB-EON) technology is a promising solution to support the exponential traffic growth in optical backbone networks. For C-band-only systems, optimal routing and spectrum allocation (RSA) policies have been investigated in the context of EON to enhance its spectrum utilization. However, for a multiband system, the same allocation strategies may not provide the best performance due to the presence of heterogeneous, complex, non-linear, physical-layer impairments (PLI), such as inter-channel stimulated Raman scattering (ISRS). This paper investigates the performance of the state-of-the-art spectrum-allocation policies in different geographies with different channel launch power for C+L band systems. Simulation results show that the Last-Fit policy performs best in terms of traffic admissibility, blocking probability, resource utilization, contiguous aligned available slot ratio, and quality of established lightpaths.

pp. 348-353

14:45 ***Dynamic Page Pattern detection and validation for Cellular Networks in DSDS device***

Rushabh Avinash Vakharia (Samsung Electronics, India); Lalit Pathak (Samsung R&D Institute India - Bangalore, India)

In Cellular Networks like 5G, when a user uses a Dual Sim Dual Standby (DSDS) device, there are high changes of Page Occasion (PO) collision across both the protocol stacks (PS) of two Subscriber Identity Modules (SIM). During such scenarios, an arbitrator module normally tries to resolve such collision using methods like round robin, alternate, weighted round robin etc. Using these approaches, the arbitrator cannot avoid the page miss very efficiently, as it is unaware of the repeat pattern of the network page. In this paper we propose an efficient way which can enhance the performance of resolution of the page conflicts by trying to determine a probabilistic network page repeat pattern dynamically. The approach relies on the learning based on the page reception of the UE over the time and determine the probabilistic page repeat pattern. This newly determined page repeat pattern will be utilized by the arbitrator to resolve conflicts in cases when the paging occasion of both stack fall nearby or overlap. As the page repeat pattern of network is dynamic in nature, in this paper we also try to address a validation mechanism which is continuous and tries to determine any such scenarios where the network page repeat pattern is changing. In case where such pattern changes the validator algorithm tries to determine the updated page repeat pattern and hence in keeping the UE informed about the recent network page repeat pattern.

pp. 354-359

15:00 ***On the Spectral Performance of Dimming-based Multilevel Modulation Schemes for VLC Systems***

Rishu Raj (Trinity College Dublin, Ireland); Abhishek Dixit (Indian Institute of Technology Delhi & IBBT, India)

Dimming support is an essential feature of any practical visible light communication (VLC) system. In this paper, we study the spectral performance of two multilevel dimming-based modulation schemes, namely multiple pulse position modulation (MMPM) and overlapping pulse position modulation (OPPM). We quantify the bandwidth (BW) required by these schemes based on their power spectral densities (PSDs) derived in this work. We compare the different types of definitions used to quantify the BW requirement and determine the most precise definition that can be used for practical implementation of these schemes. We also obtain the number of symbols that can be transmitted using these schemes at different dimming levels. Moreover, we analyze the effect of dimming and number of slots on the PSDs and BW requirements of these schemes.

pp. 360-365

15:15 ***Traffic Aware Optimal Bandwidth Segmentation for Low Latency Communication in 5G***

Ujjwal Pawar and Aditya Chilukuri (Indian Institute of Technology, Hyderabad, India); Antony Franklin A (Indian Institute of Technology Hyderabad, India)

The fifth-generation (5G) mobile technology comes with numerous enhancements to support new use cases and services. Two of these enhancements are Numerology and Bandwidth Part (BWP) in the 5G NR (New Radio) standard. While Numerology gives the flexibility for selecting Transmission Time Interval (TTI) for different types of service classes, the BWP allows a gNB (5G NR Base Station) carrier to be divided into multiple parts. Different BWPs can run different Numerologies simultaneously by selecting higher numerology for low latency use cases. In this paper, we identified the drawbacks of higher numerology under high traffic scenarios and proposed an optimal bandwidth(BW) segmentation algorithm. The proposed solution reduces the downlink latency by selecting Numerologies and BWP based on the traffic

conditions of various services. The simulation results show that the proposed algorithm can effectively adapt to the traffic load and reduces the delay and packet loss rate by up to 36% and 18.5% compared to static numerology-based scheduling.

pp. 366-371

TT11: Simulation and Modeling

14:00 ***Short-cuts on quantum network simulators***

Panduranga Rao V Marella (Indian Institute of Technology Hyderabad, India); Anubhav Srivastava (IIT Hyderabad, India); Devendra Mishra (Qulabs Software India Pvt Ltd, India); Madhuri Annavazzala (IIT Hyderabad, India); Nixon Patel (Qulabs Software India Pvt Ltd, India); Antony Franklin A (Indian Institute of Technology Hyderabad, India)

An important idea in quantum networks is that of employing virtual edges or short-cuts" between quantum nodes. These edges, which are shared entangled pairs between two nodes that are not directly connectedphysically", are expected to reduce the average latency of entanglement distribution in quantum network routing.

In this work, we show how to create such edges on an existing discrete event simulator for quantum networks called SeQUeNCe, and study the impact that these edges have on latency. Additionally, we implement a distributed routing algorithm on the simulator and demonstrate its use in conjunction with the virtual edges. We observe a reduction in latency when short-cuts are used, as is expected. Thus, with these modifications, we believe that SeQUeNCe (and other similar simulators) can be used for experimenting with advanced quantum networking protocols.

pp. 372-377

14:22 ***Analyzing Quantum Network Routing Protocols through Time-Driven Simulations***

Panduranga Rao V Marella (Indian Institute of Technology Hyderabad, India); Anvesh Bendalam (IIT Hyderabad, India); Antony Franklin A (Indian Institute of Technology Hyderabad, India); Annavarapu Phaneendra, Marapally Anuraag, Jupally Nishith, Anubhav Srivastava and Krishnam Dhanush (IIT Hyderabad, India); Devendra Mishra and Nixon Patel (Qulabs Software India Pvt Ltd, India)

Quantum routing protocols seek to distribute entanglement across different nodes of a quantum network. A recently popular approach for quantum routing is to cut down the latency times for sharing entanglement by using virtual edges in addition to physical ones. While a physical edge is associated with the presence of a quantum channel, virtual edges correspond to preexisting entanglement between some nodes which can be leveraged for entanglement swapping. Distributed routing protocols for quantum networks have been proposed and analyzed using this idea. These analyses have also been backed up by simulations.

However, to the best of our knowledge, existing simulation approaches consider a static picture, where the demands for entangled pairs are presented upfront. In this paper, we study routing algorithms through time driven simulations. Such an approach allows for the demands to emerge in real time as the simulation proceeds, and therefore mimic realistic scenarios better. This also facilitates studying routing protocols in the presence of dynamic replenishment of entangled pairs, and exposes issues like occurrence of deadlocks in the context of limited quantum resources.

As a demonstration of the approach, we show simulation results that analyze the performance of various physical and virtual graph topologies in terms of average latency time. Finally, we show the change in performance and network saturation in the presence of replenishment of entanglement resources.

pp. 378-383

14:45 ***Dynamic Network Slicing using Deep Reinforcement Learning***

Swaraj Kumar (Samsung R&D Institute, India); Satya Kumar Vankayala (Samsung R&D Institute Bangalore, India); Devashish Singh (Samsung R&D Institute, India); Ishaan Roy (BITS Pilani Goa Campus, India); Biswapratap Singh Sahoo (Nokia Networks, India & National Taiwan University, India); Seungil Yoon (Samsung Electronics, Korea (South)); Samuel Kanakaraj (Samsung R&D Institute, India)

5G network slicing provides service flexibility and enables the operator to optimize network resources and provide differentiated services at scale. Slicing in real-time is a challenge due to a large number of connected devices with wide-ranging quality of service requirements. A dynamic slicing method is needed to provide the operator the flexibility to alter the number of slices and change the resource allocation in RAN for each slice. We developed a fast and efficient deep reinforcement learning model to do dynamic network slicing that optimizes the service quality in real-time. Our solution is able to cater to a large number of users with different service requirements due to the use of neural networks to carry out the state-action mapping. Our model uses prioritized experience replay to reduce the training time which will allow the operator to update the model at frequent intervals. To prove the feasibility of the proposed model, we trained the learning agent using our model to carry out the network slicing task in VRAN. Our simulations show that the model learns the characteristics of the network slices and our novel reward mechanism enables the base station to make intelligent decisions to maximize network utility.

pp. 384-389

15:07 ***Future Backbone Optical Networks: Fiber Densification Versus Network Densification***

Anuj Agrawal (Trinity College Dublin, Ireland); Vimal Bhatia (Indian Institute of Technology Indore, India)

The increasing amount of traffic being aggregated to the terrestrial backbone optical networks (BONs) from the metro/access communication networks has caused capacity crunch in the BONs. Increasing coverage with rural and remote connectivity, wireless network densification, data hungry 5G applications, and increasing datacenters (DCs) are among the major factors that necessitated the deployment of huge amount of optical fibers around the world to connect cell sites, to interconnect DCs, to provide fiber to the home (FTTH) services, among others. Due to massive fiberization in the metro/access networks and hence to handle the increased traffic being aggregated to BONs through them, efforts are being made to increase the capacity of BONs via novel devices, fiber designs, and spectral/spatial flexibility and expansion along with the additional deployment of fibers (referred to as fiber densification) in BONs. In this paper, we focus on the topological aspect of BON and present BON densification as a promising approach for the future. We analyze the advantages of BON densification considering multicore fibers (MCFs) for which low transmission reach has been the main hindrance towards its deployment in BONs. Simulations indicate that through BON densification, MCF networks can achieve significantly low blocking, and high resiliency against multi-link failures. Furthermore, we highlight several other aspects of future communication networks which indicate that BON densification is a promising approach as compared to the conventional fiber densification.

pp. 390-395

TT9: Heterogeneous Networks

14:00 ***Utility Based Framework For Reactive And Proactive Congestion Control In SDN***

Akhil Kumar Singh Thakur and Shatrunjay Rawat (IIIT Hyderabad, India)

Congestion in a network can cause several undesirable conditions such as packet loss, retransmission of packets, etc. There have been many variations of TCP for appropriate congestion control. These variations manage the sending rate of the users based upon the feedback they get from the network. In like manner, there are congestion control methods that take leverage of the Software Defined Networking and manage congestion from the controller. In this work we aim to manage congestion by coupling the activity of both the users and network controller in an SDN. We provide a utility based framework for a joint proactive and reactive mechanism for congestion control. We propose a system optimization function and show that our user and network congestion control methods optimize the system utility. Further, we simulate our model and show that our model significantly improves the system utility.

pp. 396-401

14:15 ***Topology control for minimizing energy consumption and improving usability in mobile ad hoc networks***

Kouichi Genda (Nihon University, Japan)

Mobile ad hoc networks (MANETs) combining various types of devices, such as smartphones, drones, and robots, are becoming more significant due to the exponential growth of Internet of Things and mobile devices. To expand the practical use of MANETs, reducing energy consumption and improving usability are indispensable. In this paper, a topology control method for MANETs is proposed, where the topology determined every update interval is optimized to minimize the cumulative energy consumption for sending data while reducing energy consumption for broadcasting Hello messages. In addition, usability is improved by introducing a topology control architecture in which suitable topologies for different MANET uses are provided using various topology generation algorithms for stationary devices. As a first step for confirming the effectiveness of the proposed method, the efficacy of energy consumption reduction is evaluated through a custom simulation. In addition, the key functions are verified by conducting an experiment using different types of devices and topology generation algorithms for stationary devices.

pp. 402-407

14:30 ***IoT-Based Aggregate Smart Grid Energy Data Extraction Using Image Recognition and Partial Homomorphic Encryption***

Aniket Agrawal (Indian Institute of Technology Bhubaneswar, India); Kamalakanta Sethi (Birla Global University, India & Indian Institute of Technology Bhubaneswar, India); Padmalochan Bera (IIT Bhubaneswar, India)

The high expense of upgrading traditional analog and digital smart grid meters with network sensor devices is a major implementation cost for collecting energy consumption statistics and hence, an impediment to the grid system monitoring, observability, management strategies, and advanced metering infrastructure (AMI). A cost-effective solution for the information extraction from the meter images is to use a systematic IoT-Based periodic digital imaging methodology instead of manual reading techniques. The computations on, secrecy and integrity of this extracted data are enabled by the additive homomorphic nature of encryption in Paillier's cryptosystem, and the scheme's robustness to Replay and False Data Injection (FDI) attacks is ensured by pairing-based Boneh-Lynn-Shacham (BLS) short signature, Time Stamping, and SHA-256 function before being retrieved via the IoT device with the image sensor installed at the

industrial, commercial and residential subscriber meters. The power consumption ciphertext is subjected to decentralized progressive aggregation as it is en route online from the end-user grid meter at level 0 to the level n semi-trusted final collector for decryption through numerous minimum height spanning trees (MHST) constructed at $n-1$ geographic levels. This technique, therefore, facilitates secure, efficient, and distributed data aggregation from various sorts of users in a hierarchical fashion.

pp. 408-413

14:45 ***A Novel Server Selection Strategy for Multi-access Edge Computing***

Gayan Dilanka, Lakshan Viranga, Rajitha Pamudith and Tharindu D. Gamage (University of Ruhuna, Sri Lanka); Pasika S Ranaweera (University College Dublin, Ireland & University of Ruhuna, Sri Lanka); Indika Anuradha Mendis Balapuwaduge (University of Agder, Norway); Madhusanka Liyanage (University College Dublin, Ireland & University of Oulu, Finland)

To realize the 5G mobile technology evolution, MEC provides emerging support. Bringing cloud services to the mobile network end-user creates ultra-low latency and higher bandwidths for the mobile network. As a result, IoT domain devices can dynamically meet the running service's dynamic requirements. Virtualization enhances edge computing by reducing the number of physical resources required. With this knowledge, automated infrastructure 5G deployment is more cost-effective. Virtualization technologies should be used in the IoT space to fulfil the edge computing paradigms' goal of creating computing infrastructure at the network's edge. With virtualization, 5G server platforms will be quickly and affordably accessible for eNodeBs. Virtualized edge computing server platforms are managed and controlled using orchestration. Even though cloud-based orchestration platforms exist, the autonomous infrastructure scaling required for edge computing is not a reality. The orchestrator allows the selection of the best MEC server to begin a service. This paper proposes a mobile edge MEC server selection strategy, dependent on the MEC server's resources and link parameters. The strategy for choosing MEC servers proposed was simulated and tested for performance based on different aspects

pp. 414-419

15:00 ***Improving Service Performance through Multilayer Routing and Service Intelligence in a Network Service Mesh***

Boyang Hu (University of Nebraska-Lincoln, USA); Deepak Nadig (Purdue University, USA); Byrav Ramamurthy (University of Nebraska-Lincoln, USA)

Network service mesh architectures, by interconnecting cloud clusters, provide access to services across distributed infrastructures. Typically, services are replicated across clusters to ensure resilience. However, end-to-end service performance varies mainly depending on the service loads experienced by individual clusters. Therefore, a key challenge is to optimize end-to-end service performance by routing service requests to clusters with the least service processing/response times. We present a two-phase approach that combines an optimized multi-layer optical routing system with service mesh performance costs to improve end-to-end service performance. Our experimental strategy shows that leveraging a multi-layer architecture in combination with service performance information improves end-to-end performance. We evaluate our approach by testing our strategy on a service mesh layer overlay on a modified continental united states (CONUS) network topology.

pp. 420-425

15:15 ***A Hybrid-Combine-and-Forward Relaying scheme for Network Coded Cooperative Systems***

Sagnik Bhattacharyya, Pankaj Kumar and Sachin Sharma (IIT Ropar, India); Sam Darshi (Indian Institute of Technology Ropar, India); Akram A. Almohammedi (South Ural State University, Malaysia)

Network Coded Cooperation (NCC) proved itself worthy to meet the ever increasing demands of the next generation wireless users. In the prevalent relaying schemes, the relay either uses Amplify-and-Forward (AF) or Decode-and-Forward (DF) rigidly over all the signals received. However, some networks use Adaptive Decode-Forward (ADF) where relay only forwards the decoded data which causes resource wastage as the sources need to re-transmit the data which were not sent by the relay. This paper proposes a Hybrid-Combine-and-Forward (HCF) relaying scheme for a multi-user scenario to improve the Quality-of-Support (QoS) in a cost effective manner. With the HCF scheme, the relay dynamically performs AF on some of the received signals while DF on the rest, and stores them within a communication cycle. This decision is taken by the relay based on the Instantaneous Signal-to-Noise Ratio (SNR i) of the signal received from the respective sources. Finally, it combines all the stored signals received and transmits a hybrid superposed data to the destinations which is required to extract the second copy of the desired data. Extensive simulations provide results showing the superiority of the proposed HCF scheme over the widely used AF and DF schemes. Such a scheme can be used in a Device-to-Device (D2D) communication/ Internet-of-Things (IoT) networks or in scenarios like disaster management where sources aided by a drone/relay require reliable data at a low operational cost of the relay.

pp. 426-431

Thursday, December 16 16:00 - 17:30

TT12: Applications and Systems Configuration

16:00 ***M-3R: A Memory Based Approach for Streaming QoE Prediction under 3R settings***

Monalisa Ghosh (IIT Kharagpur, India); Chetna Singhal (Indian Institute of Technology Kharagpur, India)

The rapid growth of video traffic and demand for high quality videos has increased in the recent years. The service providers emerge out to be successful only when they provide satisfactory end user viewing experience. Due to the channel throughput fluctuations, the end users in Hypertext Transfer Protocol (HTTP) streaming endure video quality variations with time (due to bitrate adaptations) and rebuffering events (once the received video data in the buffer is played out). Hence, it is necessary to evaluate the Quality of Experience (QoE) in video streaming scenario in a continuous time (per frame) manner in order to regulate the quality deteriorations. In this paper, we have proposed M-3R predictor- A network of Long-Short Term Memory (LSTM) that evaluate the time varying streaming QoE resulting from the effects of rate adaptation and rebuffering under the 3R settings. The ``3R'' settings is a combined effect of several Full Reference (FR), Reduced Reference (RR), and No Reference (NR) Video Quality Assessment (VQA) metrics. Our proposed M-3R predictor was found to be effective in modelling the temporal dynamics of the streaming video QoE, that got reflected in the performance evaluation measures.

pp. 432-437

16:45 ***Performance Analysis of Dual-Hop THz Wireless Transmission for Backhaul Applications***

Vinay U Pai (BITS Pilani, Pilani, India); Pranay Bhardwaj and Syed Mohammad Zafaruddin (BITS Pilani, India)

THz wireless transmissions suffer from pointing errors due to antenna misalignment and incur higher path loss because of molecular absorption at such a high frequency. In this paper, we employ an amplify-and-

forward (AF) dual-hop relaying to mitigate the effect of pointing errors and extend the range of a wireless backhaul network. We provide statistical analysis on the performance of the considered system by deriving analytical expressions for the outage probability, average bit-error-rate (BER), average signal-to-noise ratio (SNR), and a lower bound on ergodic capacity over alpha-mu fading and pointing errors. Using computer simulations, we validate the derived analysis of the relay-assisted system. We demonstrate the effect of the system parameters on outage probability and average BER with the help of diversity order. We show that data rates up to several Gbps can be achieved using THz transmissions, which is desirable for next-generation wireless systems, especially for backhaul applications.

pp. 438-443

TT13: Short Papers

16:00 ***Synthesizing Voice User Interface for Augmented Reality Experience Enhancements***

Syed Shahab Uddin, Mohammed Abdul Razzak and Syed Vali Mohiuddin (Osmania University & ISL Engineering College, India)

Augmented Reality(AR) is used in several fields to make interactive models by combining the virtual and real world. While Voice User Interface(VUI) is used as a form of communication between software and the user via voice. In this research, we experimented with a VUI based experience for AR device(Android Smart Phone) to assist the existing touch-based interaction by employing speech to text(STT) and ARCore SDK. Such experiences will provide a smooth flow for several use cases such as AR shopping, AR classrooms, AR Modeling, AR tool-set navigation etc. The study concluded by successfully executing a model which utilizes the VUI system where the user can provide instructions to the AR system verbally and which will trigger the necessary commands in the AR system.

pp. 444-447

16:15 ***How Much Can Edge Offload? A Tradeoff Between the Delay and Energy Consumption***

Peiyan Yuan, Saike Shao, Lijuan Geng and Xiaoyan Zhao (Henan Normal University, China)

Sensing data offloading is an efficient means of distributing the Internet traffic. It is a cross research field of the Internet of Things and edge computing, and has received increased attention in recent years. Because edge servers have relatively limited resources compared with remote data centers, an appropriate data offloading ratio needs to be decided in advance. In this study, we formulated this problem as a sequence quadratic program incorporating two key performance metrics: delay and energy consumption. Subsequently, we used the active set method to solve the quadratic program. Finally, we built a simulation platform to evaluate the impact of various parameters on the offloading ratio. The numerical results showed that the proposed method effectively decreases the volume of upload traffic and reduces the access delay.

pp. 448-451

16:30 ***Approximations and their Validations for RIS-assisted SISO systems***

Saksham Bhushan and Sai Teja Suggala (Indian Institute of Technology Bhilai, India); Arzad Kherani (Indian Institute of Technology, Bhilai, India); Thazhathe Veetil Sreejith (IIT Bhillai, India)

Reconfigurable Intelligent Surfaces is an emerging research topic with a lot of studies being done to estimate the performance improvements with such a system under various scenarios. In this paper, closed-form approximations to the performance gain achieved in a RIS-assisted communication in a corridor model

are presented. By a network deployment of RIS and SISO Transmitter-Receiver system, these approximate expressions provide an equivalence model which states that the performance of a RIS-equipped network is similar to the performance of an appropriate spatially scaled system. The correlation between the approximated models and the exact model is verified using SimRIS Channel Simulator. Furthermore, a novel approach for assigning available RIS elements in a multi transmitter-receiver scenario is proposed which ensures resource allocation for maximum users. Several other meticulous approximations can be derived from this study by considering various structural aspects of RIS-assisted communications.

pp. 452-455

16:45 ***2-Dimenstional Reconfigurable Reflecting Unit Cell for THz Communication***

Monisha Selvaraj (Sastra University, India); Ramya Vijay (SASTRA University, India)

Several techniques have been used to design phase reconfigurable reflecting surfaces for specific conditions. Though, to attain wider beam switching is one of the thirst areas for terahertz communications. Here we propose a reflecting surface based on unit cell structure with PIN diode that is capable of switching beam up to 55 ˚ in azimuthal angle on 60 ˚ elevation angle. This work partially addresses the non-line of sight (NLOS) problems and allows quasi-line of sight wireless communication at 1.7 THz. Further, studied the impact of PIN diode placement and switching property on beam steerability. The proposed unit cell concept gives a wider switching angle with better angle stability.

pp. 456-459

17:00 ***Towards simulating dynamic routing and wavelength assignment using GNPy and SIMON***

Boyang Hu and Byrav Ramamurthy (University of Nebraska-Lincoln, USA)

In this article, we enhanced the capability of SI-MON (Simulator for Optical Networks) [1] by considering the non-linear effect of the optical network components and different industry network devices. This is achieved by using an optical route planning library called GNPy (Gaussian Noise model in python) [2] as the calculation model within SIMON.SIMON is implemented in C++ and has mainly been used as an optical network learning tool for studying the performance of wavelength-routed optical networks. It measures the network blocking probability by taking into consideration the optical device characteristics. SIMON can capture the most significant impairments when estimating the Bit-Error Rate (BER) but does not consider fiber dispersion and non-linearities. These impairments can be significant when simulating a large-scale network. GNPy, on the other hand, considers those physical impairments and can give a more accurate signal-to-noise ratio (SNR) estimation validated by real-world measurements. By integrating GNPy with SIMON, we are able to set a minimum SNR threshold, which must be satisfied by any call set up in the network. The integration of SIMON and GNPy makes the resulting simulator not only suitable for academic learning but also valuable for real-world network planning, evaluation, and deployment of optical networks.

pp. 460-463

17:15 ***A Simple Octagonal Wideband Frequency and Pattern reconfigurable Antenna for multiband operations***

Bhakkiyalakshmi R and Vasanthi M s (SRM Institute of Science and Technology, India)

In this paper an octagonal bandwidth enhanced frequency and pattern reconfigurable antenna for C and X band applications is presented. The proposed antenna can operate at dual band with wide bandwidth. The designed antenna is simple and compact in size with dimensions 32x32mm. Two slits are made on the patch one is horizontal other one is inclined. Three pin diodes placed in slits are used to achieve frequency and pattern reconfiguration. The antenna covers wide operating range in C, X and UWB band by employing

partial ground plane. The H plane radiation pattern is reconfigurable in 35°, 80°,105°,110°,175° and 185°. The radiation pattern steered to 120°, 240° and 270° in E plane. The measured results show that the deigned antenna has a -10-dB impedance bandwidth of 98.64% (3.61-11.7GHz), 75.9% (5.14-11.07GHz), 75.6% (5.15-10.86GHz) 66.09% (5.59-9.99GHz),41.7% (5.62-9.64GHz) 25.65% (3.54-4.61GHz), 25.4% (3.55-4.6GHz), 22.32% (3.7-4.66GHZ) and 22.07 (3.56-4.4GHz). This antenna can be used in UWB, WiMAX, WLAN, satellite communication and space research.

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