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TSAN

THE CHANNEL

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UNIVERSITY OF MARYLAND 18 56

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Faculty Interview

DR. RONALD PAUL HILL

"Lead with your heart and not your brain. In other words, recognize that consumers move on their emotions and not their cognitions. Thus, to be successful, you need to feel like your consumers do about your product offers in order to understand their perspectives through their lenses! Keep your technical expertise as a competitive advantage that serves you in all situations, but recognize that organizational leadership in not about who knows more but about who inspires more!"

Ronald Paul Hill, Ph.D. holds the Richard J. and Barbara Naclerio Chair in Business. He is Professor in the Marketing and Business Law Department at Villanova University.

He is socially active and responsible too and enacts as the Co-Director, Center for Church Management and Business Ethics.

He was awarded the McDonough Family Faculty Award for Research Excellence for 2014. He is full of ideas and creativity and held the position of editor for the Journal of Public Policy & Marketing from 2006-2012.

We were honored to be taught by such an experienced professor, who not only gave us knowledge as per the curriculum but also made us ponder outside the box.

1. As we know you are teaching ENTS 632, for this particular semester of Fall 2014. As lucky we are to have you as our professor,

What inspired you to teach marketing to a bunch of geek engineers? (How unique this course is?)
What inspired you to commute to College Park every week?

Or

What was your first reaction when you were asked to be a part of this unique program for telecom engineers?

Well, I was excited! This group of very capable men and women represent several distinct cultures and unique educational backgrounds compared to the people I typically teach. I recognized from the beginning that I would learn as much from you as you would from me; the best possible scenario for both of us!

2. What has been your experience as the professor with the diverse range of international students?

Or

What was your experience teaching such a unique collection of 1st generation of Global Citizens (diverse international students.)?

Over time, I recognized that I had the rare pleasure of teaching men and women who would be the next generation of global citizens and leaders. As a consequence, we needed to develop a set of skills that would ensure your success regardless of the culture in which you were embedded. Thus, we concentrated on understanding consumers and their various behaviors, how firms can react to conditions in ways that fully considered consumers' needs, and how to give a world-class presentation to support your ideas so as to be successfully heard. I believe all were satisfactorily accomplished.

3. What would be few quick things the (engineering) students can take away from this marketing course?

Recognize that understanding consumers and selecting how to respond to them will always be an art no matter how much information the firm collects. Thus, you need

to be careful about what you do but eager in its implementation so that you inspire others to follow. Additionally, technology should follow consumer understanding not the other way around! Thus, we are always looking for new and novel mays to meet consumer needs rather than going where technology leads us. Finally, be infectious in your enthusiasm for where you are leading the firm. Marketing begins with you!

4. Given all the information and insights by you during the course, I assure any ENTS student can proficiently deal with marketing for a telecommunication firm, but what is the transformation needed in an ENTS grad to be a part of the Marketing Industry.

Excellent question! Lead with your heart and not your brain. In other words, recognize that consumers move on their emotions and not their cognitions. Thus, to be successful, you need to ***feel*** *like your consumers do about your product offers in order to understand their perspectives through their lenses! Keep you technical expertise as a competitive advantage that serves you in all situations, but recognize that organizational leadership in not about who knows more but about who inspires more!*

5. This has come up time and again, should the ENTS program be rather called as Master's program in Telecommunication and Management.

My wish for you is that the program be renamed MTM, Masters in Telecommunications Management, allowing you to show the true benefit of the program's hybrid nature. This would differentiate the program and keep you from needing to get an MBA someday!

6. As alumni of the R.H .Smith school and as a Professor, do you think if ENTS could have resources from RH Smith School, we would do better? What could be those resources?

It would be very helpful if the MTM students could take more courses in Smith, do joint degrees like MTM/MBA, work alongside Smith students and benefit from their experiences and backgrounds, and use the recruiting offices in Smith. Of course, I have the luxury of not having to deal with the internal politics or resource issues!

Faculty Interview

DR. KRISHNA SAMPIGETHAYA

"Telecommunications is growing at a rapid pace and faced with formidable challenges and exciting opportunities. There is a high demand worldwide for skilled telecom professionals who can master these challenges and build on opportunities for industry's growth and society's welfare."

Krishna Sampigethaya received his BE (1997) in Electronics & Communications from Manipal Institute of Technology, India, and his MS (2002) and Ph.D. (2007) in electrical engineering from the University of Washington, Seattle, WA, USA. He then joined Boeing Research and Technology in 2007, and was selected as a Boeing Associate Technical Fellow for aviation cyber-physical systems and aviation cyber security in 2012. Since May 2014, he has been with the Department of Electrical and Computer Engineering at the University of Maryland, MD, USA, where he is the Assistant Director of the MS in Telecommunications program.

1. What made you take up the position of A. Director of the ENTS department? It's been over 10 months since you joined the department, how has the experience been so far?

A major factor in my decision to join the ENTS program is my interest in educating and guiding the next-generation workforce of networking industry. Telecommunications is growing at a rapid pace and faced with formidable challenges and exciting opportunities. There is a high demand worldwide for skilled telecom professionals who can master these challenges and build on opportunities for industry's growth and society's welfare.

Before joining the ENTS program, I believed the program was best designed nationwide to meet the growing demand for telecom professionals well into the future. The program's directorship, staff, faculty, and department leadership has people well accomplished in their fields of work and deeply committed to students. UMD and its geographic location have to be a coveted bonus for each ENTS student's professional and personal growth. My experiences after joining the program have cemented these beliefs of mine. I am much honored to be a part of ENTS.

2. Which new technologies or concepts are you introducing with your new subjects? How do you think the response has been? (Please tell us little about the subjects as well.)

In the ENTS program we now offer advanced elective courses on software-defined networking (SDN) and vehicular networks. SDN is looked up to by the networking industry as the approach to design, architect, control, and manage the future generation of networks. Vehicular networks are central to the emerging collaboration between telecommunications and automotive industries to apply networking advances, such as Ethernet, wireless, and cloud computing, to the "connected vehicle." Both subjects are building blocks for products predicted to yield billions of dollars globally. It is no surprise a large number of job opportunities are opening in these emerging markets.

Through these courses students get to: (1) learn new networking principles built on decades of conceptual advances; (2) comprehend how new networks compare to traditional networks, such as Ethernet; (3) study new network application environments and standards such as those in data centers and automobiles; (4) think innovatively and across novel interdisciplinary design spaces (e.g., data center energy vs. networking cost, network device weight vs. vehicle fuel consumption); (5) build project management skills such as in business case development and technical risk identification; and, (6) work hands-on with open-source software tools and programming languages to develop and test proof-of-concepts.

ENTS students seem to be excited by the above aspects of the course. However, as intended and expected, these advanced-level courses are to uniquely challenge and push ENTS students—beyond their comfort zones—so that they can master new technologies and design dimensions. Some students have responded by successfully finding job/internship opportunities in SDN.

3. What is it that you like/dislike about the course structure here and what modifications would you suggest?

ENTS program I think has an excellent course structure for an industry-oriented graduate program. Each student is able to develop solid theoretical and programming foundations through core courses, then take additional courses to build a distinct skill set and career path in telecommunications industry. The mix of 4 technical and 4 business courses is a long-term advantage for ENTS students. Scholarly paper is also an opportunity for students to understand their maturity in learning new telecommunications topics and the ability to write quality technical documentation. Your employer or customer benefits from your business savvy approach to technology and your ability to present ideas and technical reports. The ENTS program, however, must adapt course structure to cater to evolving industry technologies, practices, and jobs. Hence, we continue to modify ENTS course offerings, adding courses such as SDN and vehicular networks, and updating course content.

4. With new courses lined up so far, it looks like we are about to experience a revolution in ENTS program. How does the future look like for an ENTS student in the industry? Could you please elaborate on some new job trends for the students?

ENTS students must realize that the future of telecommunications has become brighter. Both the number and the diversity of jobs are on the rise. This upward trend is rooted in the fundamental shifts in telecommunications industry today, in technology, business models, and markets. SDN is opening novel job opportunities at the service providers, network operators, and network equipment manufacturers as

well as at software vendors, enterprises, and silicon vendors. Further, collaborations between telecommunications and other industries are creating new job demands; such as connected vehicle jobs (e.g., Ericsson, Ford, GM, and Toyota) that require in-vehicle networking, vehicle-to-vehicle networking, cloud computing, and cyber security skills. Furthermore, networking stakeholders are redefining their portfolios using new business opportunities. For example, network operators (e.g., AT&T, Verizon) are now going beyond 3G/4G/LTE connectivity into new areas such as applying SDN to their networks and data centers as well as cloud-based applications for network end-users. Another example is that service providers (e.g., Amazon, Facebook, and Google) who are looking to manufacture their own network devices for SDN-based control of their data centers and application traffic flows for improved quality-of-service; these service providers are also investigating connected aerial vehicles for new business opportunities.

My advice to each ENTS student is to think about who you want to hire you, rather than if an employer would hire you, then get the best job available out there that makes you happy. Students must actively network in person and online with corporate recruiters and leverage the ENTS program as a solid foundation to show their mettle and proven skillset.

5. Coming from an extra-ordinary cyber security background; and considering that majority of the ENTS students are international candidates, how do you look at their future as cyber or network security professionals?

It would be wrong to perceive that all cyber security jobs today require a US citizenship. Unlike in the past, commercial wireless and networking technologies impact many economic sectors and are critical for society's welfare. These commercial networks have cyber security considerations throughout their lifecycle, one example being threat analysis done by network/software engineers using open security standards. The need for cyber security experts is growing rapidly and this need will only accelerate with federal mandates and legislations looming in the horizon for the industry.

6. How do you place this program within a research university?

Research is vital nourishment for intellectual growth throughout your career. Telecommunications industry relies on research as a window to see and seize future new business opportunities. Students of the ENTS program are especially lucky to benefit from UMD's reputation, location, and intellectually stimulating environment accessible on campus. Research seminars and demonstrations are held throughout the year across the campus. Those striving to engage in

research are given opportunities to satisfy their needs; for example see the recent UMD fellowship achievement of ENTS student, Mr. Gaurav Sharma (http://telecom.umd.edu/news/). ENTS program, hence, provides a potent combination of advantages coveted by many top professional master's program worldwide.

7. Going by the career fairs trend at the University, should we expect to attract some new corporate partnerships to blossom?

ENTS students are being hired by leading companies located not just in the DC metropolitan area, but also from all parts of the country. ENTS program continues to engage in corporate partnerships; for example, our current partnership is with Juniper Networks benefits the program's students and course curriculum.

8. What role do you think TSAN can play in order to promote the networking courses or to make the ENTS program better overall for prospective students?

TSAN represents a strong bridge between the past, present, and future of ENTS. Providing ample opportunities for present students to interact with past and future students would be a good way to benefit all. Those of you who choose to become a part of TSAN leadership every year can think of mechanisms and opportunities that help students grow and become more attractive candidates in the job market. Indeed, to gain an upper hand in emerging telecommunications markets, a student benefits from possessing a mix of wireless/networking technical background, analytical tools, keen business acumen, and moderate programming skills. But how can TSAN help them with social development, innovativeness, ethics, communications, and other related skills needed for the professional environment? Several companies and organizations often encourage its employees to engage in external activities for their career development, such as giving seminar talks or tutorials on programming and technical topics. Can TSAN pursue such ENTS student learning opportunities? These are some thoughts I have regarding future directions for TSAN.

Alumni Article

SALIL GOYAL

Long Term Evolution or the way we call it as LTE is the present radio access technology and is regarded as the 'Fourth Generation'. LTE is an all packet based communication which provides high speed and low latency. This packet based system brings in high complications when it comes to voice calls and achieving a minimum QoS. The aim of this article is to give high level picture of the voice service over 4G systems and possibly the future generations as well. Voice over LTE (VoLTE) brings in a complex architecture and 3GPP has recommended several roadmaps to implement this service. This article very briefly discusses about the IP based multimedia subsystem (IMS), which is currently being used by carriers in the market. We shall also discuss about Voice continuity services by handover and an underlying technique referred as Single Radio Voice Call Continuity (SRVCC)

Until, few years back LTE was the biggest talk of our telecom town but soon as public was offered the LTE data services, the telecom service providers are already in the process of redefining it again by the transition to an all-IP communication system. LTE is IP based technology where voice and data services are delivered in packets as compared to the legacy networks. Legacy networks were circuit switched wherein resources were reserved for a particular communication.

Voice has been a significant source for operators to generate income, therefore; there has to be an ideal way to implement this in new technology [4]. The packet based communication brings in stringent QoS requirements and 3GPP recognized IP Multimedia Subsystem (IMS) to provide Voice over LTE (VoLTE). 3GPP has not framed a definite architecture for VoLTE; rather it has defined several components and multiple ways to implement them which makes it vendor specific. The deployment of VoLTE is a complex subject; therefore, LTE has already been deployed to provide only data services and all voice operations fall back to legacy 2G/3G network which is a CS network. This process is referred to as Circuit Switch Fall Back (CSFB). SRVCC would help in effective rollout of VoLTE in heavily crowded areas by providing efficient handover of voice bearers to legacy network whereas the data bearers can still be handled in LTE. This would not only help in generating consistent revenue but at the same time maintaining the optimum level of quality of service in LTE network [5].

IMS

The IP multimedia subsystem (IMS) is a 3GPP standard based IP connectivity which is promoted by Voice over LTE, an initiative of GSM Association (GSMA). It is considered as best alternative to support end to end voice services in LTE and is also widely accepted by industry. The IMS interface with rest of the network is shown below in figure 1. IMS interacts with the PDN Gateway (PGW) of EPC, PCRF, HSS and Public Switched Telephone Network (PSTN).

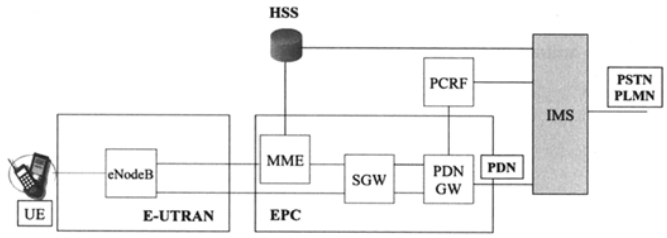

Figure1. Interfaces of IMS [2]

The figure below shows a simplified view of IMS architecture and the following talk will highlight the important links and interfaces within IMS network.

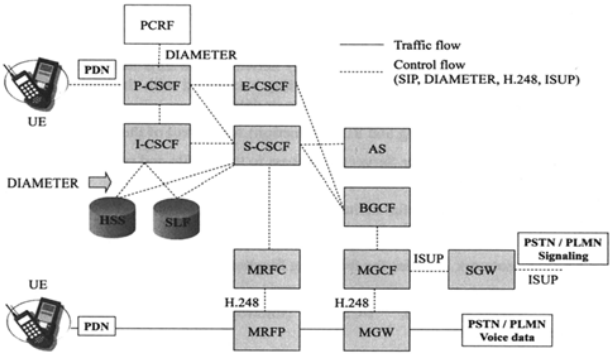

Figure2. Architecture of IMS network [2]

The prime components in this network are the four types of Call Session Control Functions (CSCF). Serving CSCF (S-CSCF) performs some key functions for UE. It performs the function of registration, maintaining session and managing calls for registered UEs [4]. It also performs the function of a location server that is in coordination with HSS [2]. Proxy CSCF (P-CSCF) is the first access point for the UE to

the IMS. It directs the requests from UE or S- CSCF to the appropriate direction towards I/S/E-CSCF or UE. It compresses the signal from UE and secures them by encrypting in order to reduce load on EPC. The Interrogating CSCF (I-CSCF) is the point of contact with other IMS and manages signaling messages from them. The Emergency CSCF (E-CSCF) is responsible for handling emergency calls routed by P-CSCF to E-CSCF, which in turn is routed to nearest emergency center. [2] [3].
The Media Gateway node (MGW) makes it possible for IMS to communicate with legacy PSTN/PLMN network. It also converts from PS to CS and vice versa. The Media Gateway Control Function (MGCF) converts signaling messages from PS to CS domain and vice versa. The Application Server (AS) provides value added services and specific IP applications such as messaging, voicemail, etc. [2] [3] [4].

Single Radio Voice Call Continuity (SRVCC)
Telecom operators like AT&T and Verizon have deployed some flavors of VoLTE in 2014 but yet there are many challenges that they have yet to overcome for instance "VoLTE Interoperability". This feature would ensure that customers enjoy seamless experience between services on different networks such as these two. Till now the voice support in LTE is given by CSFB. The deployment of IMS is a complex matter therefore it has been deployed in various phases covering the major cities at first. This means that VoLTE service is laid over legacy network and the new network will be covering small patches in legacy network. This means that for all voice calls there has to be a handover from PS domain to CS domain and the term associated with this procedure is called as Single Radio Voice Call Continuity (SRVCC).

To support SRVCC modifications has to be made in MSC server and the MME and eNodeB of EPC. The transfer of voice call is triggered by MME and eNodeB; therefore, they need to be upgraded to transfer voice bearers to new access domains. MSC is enhanced to make sure that radio access network in CS domain is prepared to accept the transfer of access domains. However, no upgrade is required in GERAN or UTRAN. A new SV interface is introduced between MME and MSC, which is based on GPRS Tunneling Protocol (GTP). [1] [4] [5]

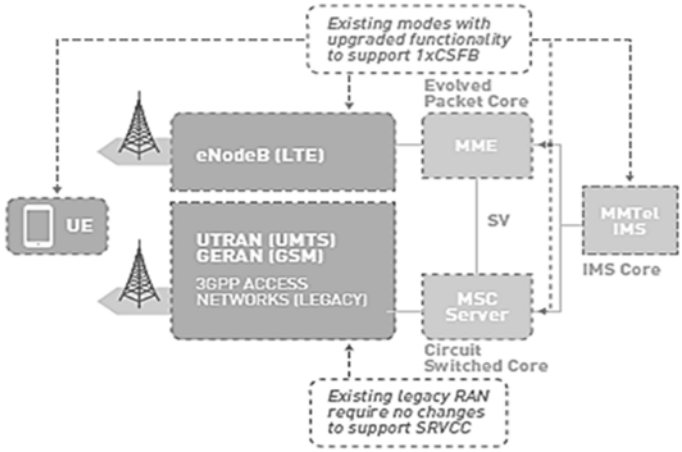

Figure3. SRVCC architecture

The handover of voice call in SRVCC has two major steps, session transfer commands and IRAT handover execution. IMS maintains the vital control over UE during the handover of voice call in SRVCC [5]. The UE regularly performs the measurement of signal quality of its active EPS bearers. Based on these reports UE would decide the handover of particular EPS bearers to another access domain and the retention of some EPS bearers to existing PS domain. After receiving the test report from UE, the eNodeB triggers the shift of bearers from PS domain to CS domain [1]. The MME initiates

the handover by sending Session Transfer Request to IMS [5]. The P-CSCF in IMS request PCRF to provide QoS of different bearers; the right bearer for handover is picked based on that report [1].

Conclusion & Future aspects

Operators can gain the benefits of VoLTE and IMS by filling in the gaps in their network by SRVCC and still claim to have the next generation system. Due to increasing demand of better speeds for effective communication the operators are looking up-to IMS to provide effective solution. The SRVCC solution is already in line to provide initial handover solution; therefore, the IMS based VoLTE seems like a legitimate solution.

However the deployment of VoLTE and IMS at the traditional telecom glacial speed comes as no surprise owing to the high cost of hardware and the mammoth upfront investment versus a credible but debatable cost benefits. With the recent development by Huawei to virtualize VoLTE by NFV platform, the growth rate of VoLTE deployment is expected to grow many folds. The cloud based service layer not only allows big/small carriers to competitively deploy VoLTE services but also manage the inflow of money in installing new hardware and take the next road to be innovative businesses.

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Student Article

ABHISHEK SUBRAMANYAM

"The FCC Speed Test is an application for Mobile devices that was designed to measure mobile broadband data performance. This was brought in by the FCC as a part of the Measuring Broadband America program. The project was based on the ideas of – "openness and transparency" and "bring greater clarity and competition to the broadband service marketplace."

Available on the Google Play store and Apple App store, this app can be used by everyone to get a clear idea and understand more about their network is working for them. This app also keeps a log of the tests on weekly, monthly and yearly basis for reference.

A must app for the mobile Data hungry user!"

The FCC Speed Test App:

In 2012, the FCC devised a plan to introduce the FCC Speed Test app for Android and iPhone devices to ensure a transparent, collaborative and crowdsourcing initiative to collect data from users/volunteers who have downloaded the app. The FCC app is available for free on the Google Play Store and Apple store. This app was developed as a venture by the FCC and leading wireless providers, as an initiative to transparently give real time tests, and maintain the participants/user privacy to the highest level.

How the FCC Speed Test app works:

The application measures four active parameters of mobile broadband performance which are:

a) Download Speed
b) Upload Speed
c) Latency
d) Packet loss

Apart from these main benchmarks, other passive information such as Signal Strength of connection, Device manufacturer, Model of the smartphone are collected. The test happens in the background, and the estimated usage of data by this app will not exceed 100 Mb a month.

Technical details of how the app works:

Mobile Performance Data Dictionary is a technical compilation of what every technical term used in this app means. The terms and parameters used in these tests are described from the layman point of view. Broadly, these are divided into Tests, Metrics and conditions under which these take place. All these are described with an example test result for each.

Type of Tests:

a) **JHTTPGETMT** :
Describes results of the active test for Download performance
b) **JHTTPPOSTMT**:
Describes results of the active test for Upload performance
c) **JUDPLATENCY**:
Describes results of active test for Latency
d) **CLOSESTTARGET**:
Describes the nearest measurement server that the client enables as it gets activated for testing, which is the nearest server that is used by app for testing.

Types of Metrics:

a) phone_identity :
A passive metric that describes features of the handset and installed operating system. (This is essential, as in Android OS, FCC app is allowed to run automatically in the background, which is ideal, but iOS supports only manual tests.)

b) network_data :
Passive metric that describes the features of wireless connectivity of the active network connection. Information such as network_operator_code, network_type, phone_type_code are few parameters described.

c) gsm_cell_location:
Describes the location of handset determined by the GSM provider.

d) cdma_cell_location:

Describes the location of handset determined by the CDMA provider.

e) **cell_neighbor_tower_data:**
Describes the location of handset determined by the GSM provider.

f) **location:**
Describes the location of the handset determined by network provider or GPS.

Conditions under which these measurements are made:

a) **param_expired :**
Tells if the value of a parameter has been expired when it is used to get control of the value of closest target.

b) **netactivity :**
Describes the traffic sent and received by the handset.

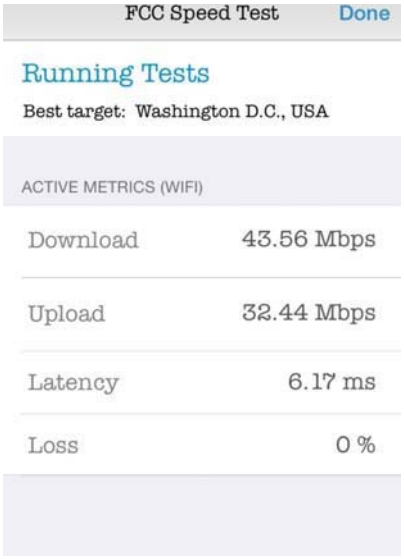
c) **cpuactivity:**
Describes CPU activity of the handset during a testing period.

FCC speed test is widely considered to be the most accurate as it is totally transparent. The source code for testing process is also available on the FCC website. Other speed test benchmarks such as OOKLA do not reveal their testing criteria and procedures.

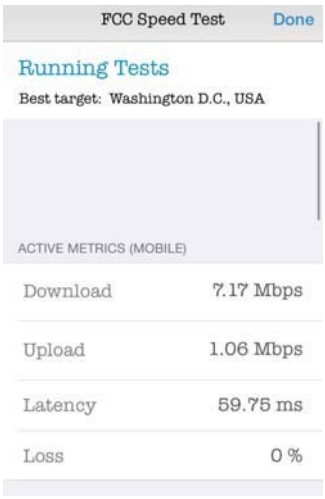
Following are few snapshots of the app as taken from iPhone 6 which is an LTE CAT 4 device. It is advised for users of Samsung, HTC, Nexus devices to test this as most of them support LTE CAT 5. The new Galaxy S6 is LTE CAT 6 ready, so if any major telecom service operators rollout CAT 6 networks, we can see the latest and the greatest version of LTE.

To all who install this app and run tests -you are going to be contributors to the National Broadband Plan of America!

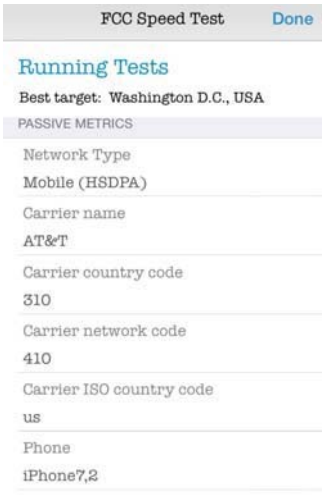
a. Test on Comcast WiFi



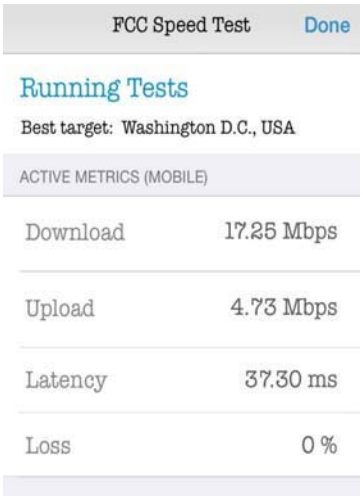
b. Test on UMD campus WiFi



c. Active Tests on AT&T HSDPA



d. Passive Test on AT&T HSDPA



e. Active test on AT&T LTE

f. Passive Test on AT&T LTE

g. Yearly average download speeds

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Student Article

NIKHIL PRATHAPANI

Voluminous data transfer has become inevitable to serve the needs of millions of diverse users ranging from scientific community, Corporate Businesses to common man. In the present era, each and every user in the world would like to get the fastest and most reliable data transfer. Although the web is free, the protocol employed isn't always available at free of cost. Apart from traditional TCP and UDP protocols, many users in the scientific community and corporate sector use protocols like Aspera [1], FileCatalyst [2], Signiant [3] etc. But the aforementioned protocols are paid data protocols and are not available to everyone on the web. This leads to a situation where we have to rely on open-source data transfer protocols such as UDT (UDP based data transfer protocol), UFTP (Encrypted UDP based FTP with multicast), Tsunami UDP, GridFTP etc. The paper mainly focuses on performance analysis of the aforementioned open-source data transfer protocols and also discusses trade-offs among them."

I. INTRODUCTION

Each data transport protocols has its own set of advantages and disadvantages. Based on the requirement, different protocols are used in various fields of Science, Technology and Computing. The protocol employed must be able to serve a certain application. For instance, companies use different protocols dictated by the necessities of larger trading partners with established e-commerce programs tied to one or two specific protocols. It is always tough to migrate from one protocol to another because of the huge Sunk costs involved in developing a software and replicating the same. If a migration or upgrade is needed, the huge sunk costs force the companies to increase the prices for their product by stating compatibility of upgraded software as a pretext.

The major parameters or metrics to be considered before employing a protocol for a particular application are Privacy, Authentication, Integrity, Non-repudiation, Message Size, Compression, Speed, Restart, Certification, Firewall friendly, and Architecture [4].

II. QUALITY METRICS FOR DATA TRANSFER PROTOCOLS

The major quality metrics for open source data transfer protocols and their brief definitions are as follows:

A. Privacy

Privacy means that the transfer of files or data between client and server or between clients within a network cannot be viewed or disrupted by a private party. Encryption techniques are used in order to ensure privacy in business-critical transactions or data transfers. Encryption levels can be further subdivided into two layers of protection for data transfers. They are Transport encryption and Payload encryption. Transport encryption secures the entire server-client or intra-network connection so that all data contents cannot be viewed. Payload encryption ensures that the data is encrypted before sending it over the network.

B. Authentication:

Authentication requisites identity credentials before granting access to a system allows businesses to control their content and protect their data. There are three steps involved in protocol authentication. The first step is requisition of Username and Password, where users are assigned a unique name and password before allowing connections for data transfer. The second step is the Client Authentication, where keys or certificates provide the identifying credentials for clients adding a higher level of authentication. Digital certificates are often signed by a certificate authority which in turn increase security. The third step is Session Authentication, where Client authentication is specified within the transport layer. Session authentication makes use of keys or certificates within protocol commands to further authenticate users prior to exchanging any payload.

C. Integrity:

Integrity check is one of the prominent metric for any protocol. Integrity check involves verifying whether the sent data is identical to the received data. Integrity check also involves identification of duplicate packets at the receiver side and ignoring them. A value called checksum is calculated using the technique of Hashing, which is nothing but integrity check. The checksum same when calculated from the same set of data, regardless of the device used. Any changes to the data set will result in a new number being generated.

D. Non-Repudiation:

It is essential to know when discrepancies are extant in the data being transferred. Non-repudiation warrants that a user cannot later challenge having sent or received a file. There are two parts to non-repudiation that are commonly used together. The first part is Receipts, where the file transfers are established with a returned document or message giving the status of the transfer. In many cases, receipts also confirm integrity checks also. The second part is signing, where Digital certificates are used to provide the user a way to "sign" a file or receipt. Public and private keys confirm that signatures can be verified by the receiving side and prohibit data transfers from unauthorized users.

E. Message Size:

The Range of file sizes supported by a protocol helps in finding out the best fit protocol that suits an application.

F. Compression:

Afore data transfer, the sender compresses the file size to be sent to the receiver. This results in transmission of data even over channels with smaller bandwidths.

G. Speed:

Smaller overhead on a protocol increases speed. Network conditions, bandwidth, and latency all have a multifaceted impact on protocol performance.

H. Restart:

Restart potentials allow a protocol to reestablish a failed or intermittent file transfer from the point it was stopped as opposed to restarting the transfer from the beginning. This metric is quite useful during large file transfers.

I. Certification:

Certification with governing organizations or interoperability testing groups ensures the guaranteed performance of a protocol.

J. Firewall friendly:

If the protocol is compatible with the firewall and does not require too many port changes, then it is termed as firewall friendly. Although some changes to ports and port ranges are inevitable, it is vital that the protocol is not requiring too many port changes.

K. Architecture:

The Architecture of a protocol determines how a protocol communicates from point to point. The two major types of architectures are peer-to-peer and

client-to-server architectures. The former allows simultaneous data flow from sender to receiver and file transfers are always initiated from the side that has the data. In the latter, file transfers are always initiated from the client side and also requires the server to be in a constant listening state, but does not require the client to do the same.

III. UDT

UDT [5] stands for UDP-based Data Transfer Protocol. It is Application level, end-to-end, unicast, reliable, connection-oriented, streaming data transport protocol. It uses layered architecture.

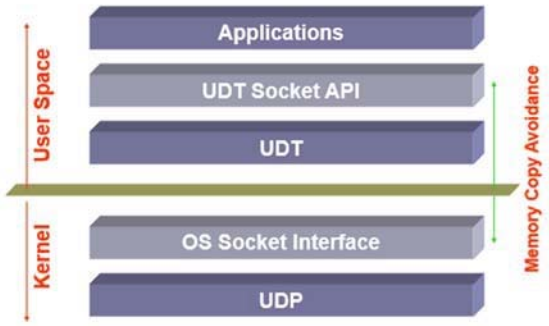

Figure 1: Layered Architecture of UDT

IV. TSUNAMI UDP

Tsunami UDP [6] protocol is a user-space file transfer protocol that uses TCP control and UDP data for transfer over very high speed long distance networks (≥ 1 Gbps), aimed to provide more throughput than feasible with TCP over the same networks. Tsunami UDP includes FTP like client and server command line applications for normal file transfers. It has additionally been extended for high rate real-time data streaming in eVLBI radio astronomy and geodesy (VSIB, PCEVN DAQ). It is licensed under the original IU open source license.

V. UFTP

UFTP [7] stands for Encrypted UDP based FTP with multicast. UFTP is an encrypted multicast file transfer program, designed to securely, reliably, and efficiently transfer files to multiple receivers concurrently. This is useful for distributing large files to a large number of receivers, and is especially useful for data distribution over a satellite link (with two way communication), where the inherent delay makes any TCP based communication highly inefficient. UFTP also has the capability to communicate over disjoint networks separated by one or more firewalls and without full end-to-end multicast capability through the use of a UFTP proxy server.

VI. GRIDFTP

The four major features of GridFTP protocol [8] are Performance, Checkpointing, Third-party transfers and Security.

A. Performance: GridFTP protocol uses parallel TCP streams and multi-node transfers to achieve high performance.

B. Checkpointing: GridFTP protocol requires that the server send restart markers (checkpoint) to the client.

C. Third-party transfers: In GridFTP protocol, the control and data channels are separated, enabling third-party transfers, i.e. the transfer of data between two end hosts, facilitated by a third host.

D. Security: GridFTP protocol provides strong security on both control and data channels.

Control channel is encrypted by default. Data channel is authenticated by default with integrity protection and encryption.

Comparison Metric	UDT	Tsunami UDP	UFTP	GridFTP
Data Transfer Rate	27-28 Mbps	~25 Mbps	~25 Mbps	300 Mbps
Multi-threaded	No	No	No	Yes
Encryption	No	No	Yes	Yes
Server with secure user accounts	No	No	No	Yes
IPv6 support	Supports IPv6	No	No	No
UDP transport layer	Yes	Yes	Yes	No UDP transport layer
Support for any packet loss	No Support for packet loss	No Support for packet loss	No Support for packet loss	Supports packet loss
Automatic retry and resume (ARQ)	No ARQ	No ARQ	No ARQ	ARQ is implemented
Predictability of data delivery	No Predictability	No Predictability	No Predictability	Predicts data delivery
Jumbo Packets	Yes	No	Yes	No
Feedback control for stable transmission	Limited feedback control	No feedback control for stable transmission	Limited feedback control	Limited feedback control

Figure 2: Comparison of Quality metrics for various open source data transfer protocols [9]

VII. CONCLUSION

It has been evident from the above table that there are trade-offs between performances of various protocols and their usage is dependent on the application. Each of the afore-discussed protocols have their own advantages and disadvantages. From the above table it is clear that GridFTP is the most stable, secure and high-performing open source data transfer protocol. Although GridFTP shares several of the limitations of the open-source UDP based protocols but is better equipped with functionalities including multi-threating, encryption, secure user accounts and support of packet loss [10]. But setup for these open source data transfer protocols is a tedious process due to many compatibility issues and as a result many companies prefer paid data transfer protocols [11] over these open source protocols. But there is a major turn-around possible in near future where everyone uses these open source data transfer protocols, given the backward compatibility issues are fixed and the libraries are expanded to work on different platforms.

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Student Article

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"We are surrounded by Signals, a lot of wired and wireless Communication happens around us all the time. These transmissions need to be reliable and efficient and to check the efficiency of these transmission medium and sources, we use Signal Analysis.

This article emphasis on the wireless measurement devices used for the Wireless Spectrum analysis. It first explains the fundamentals of Spectral Analyzers and the various kinds available in market. While revealing about the existing Analyzers it focus on the handheld form of analyzers. Then we enlist various advancements that are being used to improve the handheld Spectrum Analyzers so that soon these portable devices would surpass the standards of the heavy-duty benchtop equipment."

Understanding the wireless spectrum is like understanding the extent of space; it is vast, it is seemingly unlimited, yet we can make use of only a very small part of it.
Astronomers can be compared to Communication Engineers, who try to understand this widespread resource using telescopic tools like Spectrum Analyzer. [1]

Many times the terms Signal Analyzer and Spectrum Analyzers are used interchangeably. However, a Spectrum Analyzer is restricted to measurement of the amplitude characteristics, whereas a Signal analyzer is more enhanced due to the programming or software incorporated enabling higher signal processing capabilities. The distortion measurements, pulsed measurements, Power and Noise Measurement of a Device under Test (DUT) are best derived by Spectrum Analysis; whereas, demodulation measurement or the modulation quality analysis is best understood via vector signal analysis. A Spectrum Analyzer can be used to decipher the spectral composition of other kinds of signals like optical signals (light waves) or acoustic waveform (pressure waves) which can be considered through the use of an appropriate transducers. [2]

The structure of the Spectral Analyzers has evolved a lot in time. A primitive spectrum analyzer can be considered fundamentally to be made of a tuned receiver with selectable intermediate frequency Bandwidths, projecting output from logarithmic /linear detector to a display screen usually CRT.[3]

The Modern Spectrum Analyzers are fundamentally **Vector Signal Analyzers** with a wide Bandwidth for the Digital IF. [4] This gives it the advantage of both the FFT and swept analyzers.

It deploys FFT analysis for faster analysis over a narrow band only when it is certain that the range of the frequency of the input test signal is less than the IF Bandwidth.
Whereas, if the frequency range of the test signal is unknown or known to be larger than the IF Bandwidth Swept analysis technology will be used. [5] These have better LO speeds so higher sampling rates are deployed which are facilitated by digital IF filters.

Dynamic Signal Analyzer –DSA(FFT based SA) attenuates the amplitude of input test signals , if needed, and then passes the signal through anti-aliasing filter so as to have the frequency of the test signal elements within the permissible range to be sampled. This sampling helps in converting the input analog signal to digital which then clustered into blocks via windowing and subjected to the Fast Fourier transform analyzers. A Fast Fourier Transform (FFT) based Analyzer is basically the analyzer used for the low frequency signals like Sonars or audio Analysis

Swept-Tuned Based Analyzers: are used for signals in Cellular Communication / WLAN, and Radar Technology .It measures the amplitude of the input signal against frequencies in the bandwidth that it sweeps across using Local Oscillator (LO). [6] Example of a swept based receiver would be the Super Heterodyne Receiver.

Real-Time Spectrum Analyzer (RTSA) was a benchtop equipment because of the immense data it captures and stores, but due to immense improvement in the DSP technology it is now available as USB plug-in for PCs and handheld modules.

The RTSA, in addition to everything the Vector Signal analyzer does, processes the signal meticulously. It has a Density Display which would represent the signal with different colors depending upon the density i.e. the energy distribution over frequency. It also has a Spectrogram which has colors representing different amplitudes on a graph of frequency vs time. These are possible because of the thousands of scrollable buffers that are processed right after the FFT. [7]

Partially the credit for the advancement in the Signal Analysis goes to the modern techniques of calibrations. Other than the legacy OSL calibration, which no doubt is still the most reliable method, but rather inconvenient in the field. So rather some SA have faster calibration techniques in which the terminal has to be just connected once on test port given that Frequency range of DUT doesn't change , so it is much faster in the field.

Furthermore, some Spectrum Analyzers come with software based calibrations which interpolated extra data points within the entire frequency range so that the calibration is not to be repeated in case the frequency range of the DUT changes. [8]

These Spectrum Analyzers are widespread and are used all throughout in different arenas of Telecommunication. The Cellular domain has Anritsu handheld devices testing different frequency using different products like BTS Master, Site Master and Spectrum Master.

Wi-Fi testing tool like the Wi-spy along with chanalyzer is essentially a spectrum analyzer which decodes the spectral information to the WLAN specifications. Trending now is software based SA, like the Raspberry–Pi based Network Analyzer.

This immense growth in the portability of the Spectrum Analyzers and still keeping up to the standards, reinforces my belief that that soon these portable devices would surpass the standards of the heavy-duty benchtop equipment.

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