Research Journal of
Information Technology

ISSN 1815-7432

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Information Technology 3 (4): 207-214, 2011
ISSN 1815-7432 / DOI: 10.3923/rjit.2011.207.214

Distinguishing Employment of Stream Control Transmission Protocol over LTE-Advanced Networks

Ghassan A. Abed, Mahamod Ismail and Kasmiran Jumari
Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia

Corresponding Author: Ghassan A. Abed, Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia

ABSTRACT
Stream Control Transmission Protocol (SCTP) is a reliable connection-oriented transport protocol which is very similar to the well-known and widely used Transmission Control Protocol (TCP). As TCP, STCP implements congestion and flow control, detection of data corruption, loss or duplication of data and supports a selective retransmission mechanism. In addition it makes it possible to benefit from improved features such as the handling of multi-streams to implement transport network redundancy easily and avoid head-of-line blocking or multi-homing. There have been some debates in 3rd Generation Partnership Project (3 GPP) working groups on which transport protocol would be the most suitable for the control plane of future networks generation such as Long Term Evolution Advanced (LTE-Advanced) networks to support signaling message exchange between network nodes. LTE-Advanced represents the next generation in systems of wireless communications which aim to accomplish main advance of the current third generation systems, by reaching to uplink (UL) rate of 500 Mbps and to 1Gbps in downlink (DL). To achieve this goal, the society of 3GPP is presently evolving LTE-Advanced as a development of the standard of LTE. SCTP is an end-to-end transport protocol that provides services heretofore unavailable from either of the workhorse transport protocols that have supported the Internet for more than twenty years: reliable, connection-oriented TCP or unreliable. This study offers an overview to employing SCTP over LTE-Advanced networks and analyzes the key features of this protocol and its role when applies over next generation communications systems.

Key words: SCTP, TCP, LTE, LTE-advanced, E-UTRAN control plane

INTRODUCTION
Form the end of 2009, the LTE system has been installed as a normal growth of GSM (Global system for mobile communications) and UMTS. The ITU (International Telecommunication Union) has devised the IMT-Advanced term to recognize the new mobile systems that capable to going beyond IMT 2000 (International Mobile Telecommunications). Exactly, the requirements of data rate have been amplified. Since 2009, 3 GPP has operated on a research with objective to identify the required enhancements for LTE systems to achieve the requirements of IMT-Advanced. In September 2009 the partners of 3 GPP have prepared the official suggestion to the proposed new ITU systems, represented by LTE with Release 10 and beyond to be the appraised and the candidate toward IMT-Advanced. After attaining the requirements, the main object to bring LTE to the line call of IMT-Advanced is that IMT systems must be candidates for coming novel spectrum

bands that are still to be acknowledged (Kottkamp, 2010; Kiiski, 2010). LTE-Advanced is applying various bands of spectrum which are already valid in LTE along with the future of bands of IMT-Advanced. More developments of the spectral efficacy in downlink and uplink are embattled, specifically if users serve at edge of cell. Also, LTE-Advanced aims quicker exchanging between the resource of radio states and between additional enhancements of the figures of latency. All at once, the bit cost must be decreased (Stencel *et al*., 2010). IMT-Advanced represents the next generation in systems of wireless communications which aim to accomplish other main advance of the current third generation systems, by reaching to uplink (UL) rate of 500 Mbps and to 1Gbps in downlink (DL). To achieve this goal, the society of 3GPP is presently evolving LTE-Advanced as a development of the standard of LTE (Nam *et al*., 2010).

ARCHITECTURE OF LTE-ADVANCED

3GPP identified in Release 8 the requirements and features and requirements of the architecture of Evolved Packet Core (EPC) which that serving as a base for the next generation systems (Akyildiz *et al*., 2010). This identification specified two main work objects, called LTE and system Architecture Evolution (SAE) that leading to the description of the Evolved Packet Core (EPC), Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and Evolved Universal Terrestrial Radio Access (E-UTRA), where each of it is correspond, respectively to the network core, system air interface and the radio access network. EPC is responsible to provide IP connection between an external packet data network by using E-UTRAN and the User Equipment (UE). In the environment of 4G systems, the radio access network and the air interface are actuality improved while the architecture of core network (i.e., EPC) is not suffering large modifications from the previously systematized architecture of SAE. In Fig. 1, the E-UTRAN architecture of LTE-Advanced is shown (Abed *et al*., 2011a, b).

The main part in the architecture of E-UTRAN is the improved Node B (eNB or eNodeB) that is provide the air interface between the control plane protocol terminations and the user plane towards the User Equipment (UE). Both of the eNodeBs is a logical element that serving one or more E-UTRAN cells and the interfacing between the eNodeBs is termed the X2 interface. Completely, the interfaces of network are built on IP protocols.

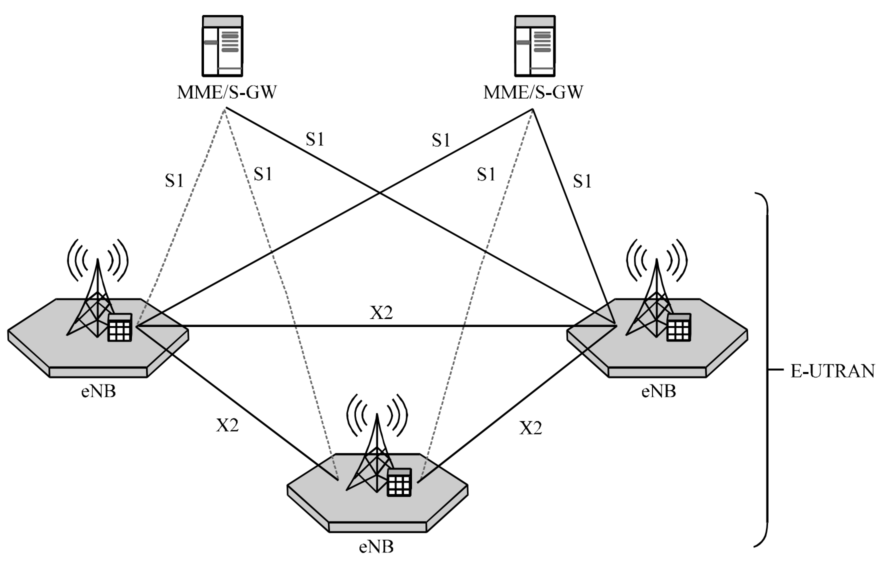

Fig. 1: LTE-Advanced E-UTRAN architecture

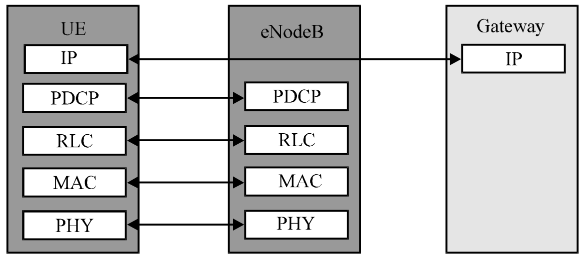

Fig. 2: User plane protocol

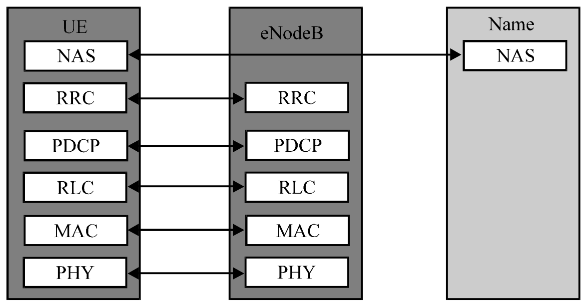

Fig. 3: Control plane protocol architecture

User plane protocol and control plane protocol stack: The stack of user plane protocol is shown in Fig. 2. Form the Fig. 2, the Radio Link Control (RLC) and the Packet Data Convergence Protocol (PDCP) layers usually concluded in RNC on the network side are now concluded in eNodeB.

The control plane protocol stack demonstrates in Fig. 3, where the Radio Resource Control (RRC) functional conventionally applied in RNC is integrated in to eNodeB (Tapia *et al*., 2009). The layers of Medium Access Control (MAC) and Radio Link Control (RLC) are implementing similar roles to user plane. The RRC functions are include paging, system information broadcast, radio bearer control, connection management for RRC, measurement reporting to UE and mobility functions. In the MME network side, the Non-Access Stratum (NAS) protocol is terminated while on the terminal side, the UE executes functions such as Evolved Packet System (EPS), authentication, security control and bearer management.

S1 and X2 interface protocol stacks: In the Fig. 4 and 5, the interface protocol stacks S1 and X2 are presented where the protocols that used are similar in the two interfaces. The interface between S-GW and eNodeB are interconnected by S1 user plane interface (S1-U). This interfacing is used GPRS Tunneling Protocol-User Data Tunneling (GTP-U) over UDP/IP transport. Also it is provide a nonguaranteed delivery to the user plane PDUs between S-GW and eNodeB (Khan, 2009). GTP-U is a comparatively simple IP and is based on tunneling protocol that allows a lot of tunnels between end points sets.

In details, the S1 interfacing is separating the EPC and the E-UTRAN. It is splitting in to two interfaces; the first is S1-U that is transfers traffic data among S-GW and the eNodeB and the second is S1-MME that is a signaling the interface between the MME and eNodeB. In other hand, the X2 is the interfacing between the eNodeBs and also involving two interfaces; the first is X2-C which is the control plane interface between eNodeBs and X2-U is the user plane interface between

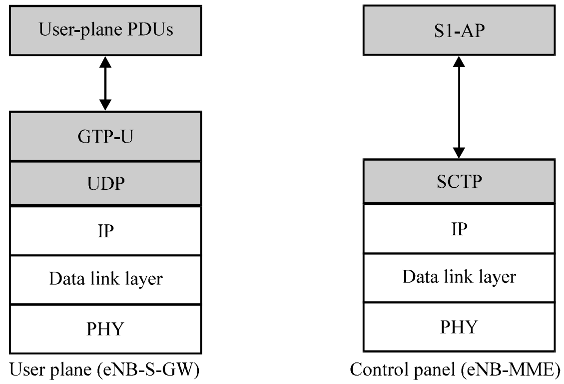

Fig. 4: S1 interface user and control planes

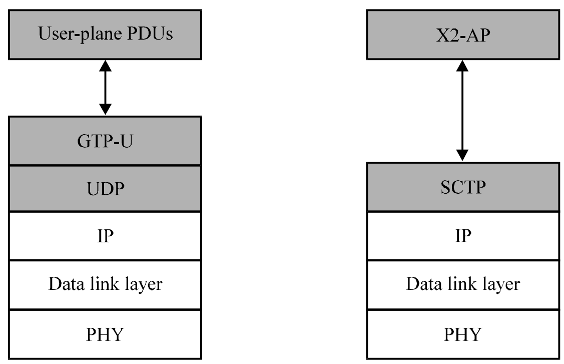

Fig. 5: X2 interface user and control planes

eNodeBs. It is supposed that always there is an X2 interface between eNodeBs which is to provide communicating between each other (Ghosh *et al.*, 2010). S1-MME represents the S1 control plane interfacing between MME and eNodeB. Similarly, the transport network layer and user plane is based on IP transport and in case of reliable transport to the signaling messages; the Stream Control Transmission Protocol (SCTP) is applied over IP top. These protocol functions analogously to TCP confirming reliable, in sequence transmission of all messages with congestion control. The signaling protocol of application layer are mentioned to as X2 application protocol (X2-AP) and S1 application protocol (S1-AP) for X2 and S1 interface control planes correspondingly.

SCTP OVER LTE-ADVANCED

The SCTP is a transport protocol specified in RFC 2960 (Stewart *et al.*, 2000), operating at an equivalent level in the stack as User Datagram Protocol (UDP) and TCP. Compared to TCP and UDP, SCTP is richer in functionality and also more tolerant against network failures. The SCTP on the other hand, also used as transport protocol at several interfaces in EPS, is a less known transport protocol (Olsson *et al.*, 2009). The purpose of the SCTP is to provide a robust and reliable signaling bearer. To achieve this, SCTP provides appropriate congestion control procedures, fast retransmit in the case of message loss and enhanced reliability. It also provides additional security against blind attacks and will be used to increase security in connecting the UMTS networks of different operators (Kaaranen, 2005).

In SCTP, an association is defined by a (Source IP, Source Port, Destination IP, Destination Port) group. When comparing TCP and SCTP from a functional perspective, SCTP provides two key features which TCP does not support the multi-streaming and multi-homing. In the SCTP domain, a stream is a unidirectional sequence of user messages to be delivered to upper layers. As a consequence, bi-directional communication between two entities involves at least a pair of streams, one for each direction. The multi-streaming is the feature from which the STCP name is actually derived. It allows setting up several independent streams between two peers. In such a case, when a transmission error occurs on one of the stream, it does not affect data transmission on the other streams. In contrast, TCP only provides one stream for a given connection between IP peers which may cause additional data transmission delay when a packet or group of packets is lost. When a transmission loss occurs on a TCP connection, packet delivery is suspended until the missing parts are restored, as in-sequence data delivery (or data sequence preservation) is a key TCP feature (Lescuyer and Lucidarme, 2008).

SCTP provides new services and features for IP communication. For the past twenty years, reliable communication service has been provided by TCP and unreliable service has been provided by UDP. Neither TCP nor UDP can handle multi-homing, or the ability to send information to an alternate address if the primary becomes unreachable. SCTP's closest competition, TCP, will need to improve or become a relic. Many of the features found in TCP and UDP can also be found in SCTP. A comparison between SCTP, TCP and UDP is provided in Table 1 (Stewart *et al.*, 2008).

As such, it is now going through the difficult post-standardization phase of achieving large-scale Internet deployment-firewall designers must be convinced to let SCTP packets through, stacks must be updated and so on. SCTP was originally designed to efficiently transfer telephony signaling data across the Internet but its features make it attractive for other applications too (Welzl, 2005). The SCTP protocol is well known for its advanced features inherited from TCP that ensure the required reliable delivery of the signaling messages. In addition it makes it possible to benefit from improved features such as the handling of multi-streams to implement transport network redundancy easily and avoid head-of-line blocking or multi-homing. An area of simplification in LTE is the direct mapping of S1 Application Protocol (S1-AP) on top of SCTP. This results in a simplified protocol stack with no intermediate connection management protocol, since the individual connections are handled directly at the application layer. Multiplexing takes place between S1-AP and SCTP whereby each stream of an SCTP association is multiplexed with the signaling traffic of multiple individual connections (Alcatel-Lucent, 2009).

There have been some debates in 3 GPP working groups on which transport protocol would be the most suitable for the E-UTRAN Control plane, to support signaling message exchange between network nodes. Among the three most obvious candidates, UDP was quickly ruled out as not being reliable enough. From a high-level perspective, SCTP and TCP are quite close to each other, as they both support reliable and ordered data delivery, as well as congestion control to regulate network data flow. The fact that SCTP is message-oriented and supports framing of individual messages as opposed to TCP which is octet stream-oriented and does not preserve transmitted data structure. In SCTP, messages are transmitted as a whole set of bytes (provided the maximum length is not reached) which helps to improve transmission efficiency. SCTP in E-UTRAN Transport Network In the S1 interface (and the same applies to the X2 interface described below), SCTP is used over the usual IP network layer. There is only one association per instance of S1 interface. Over this association, one SCTP stream is used for all common procedures-such as the paging procedure- between two pieces of equipment. Regarding all dedicated procedures-which include all

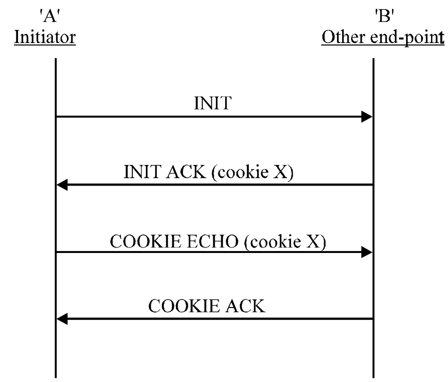

Fig. 6: The steps of SCTP association setup

Table 1: Comparison between, SCTP, TCP and UDP

	SCTP	TCP	UDP
Connection oriented	Yes	Yes	No
Reliable transport	Yes	Yes	No
Preserve message boundary	Yes	No	Yes
In-order delivery	Yes	Yes	No
Un-order deliver	Yes	No	Yes
Data checksum	Yes (32-bit)	Yes (16-bit)	Yes(16-bit)
Flow and congestion control	Yes	Yes	No
Multiple streams within a session	Yes	No	No
Multi-homing support	Yes	No	No
Protection against SYN flooding attacks	Yes	No	N/A

producers which apply to a specific communication context-they all are supported over a limited number of SCTP streams. For illustration, Fig. 6 describes the four steps of a SCTP association establishment. On reception of the INIT message, the receiver builds a cookie and sends it to the initiator using the INITACK message.

To enable the association, the initiator must answer a COOKIE ECHO containing the same cookie as received in the INITACK. Resource reservation related to the association is only performed by the .B. side on reception of a COOKIE ECHO. At the end, the COOKIE ACK is sent back to the initiator to acknowledge the association setup. Resource attack is prevented by building the COOKIE in a special way. In principle, the receiver of the INIT message is using a secret key and a hash mechanism to create it, so that on reception of the COOKIE ECHO, it can then validate that the cookie was actually previously generated by the receiver. This protection is based on the fact that the receiving entity (the .B. part in the diagram) does not reserve resources or keep context pending during the INIT phase. Resource activation is only performed when a valid COOKIE ECHO message is received. Of course, this assumes the rogue initiator does not process the answers which is generally the case for denial of service attacks. The cookie structure is not fully specified by the SCTP recommendation but it may possibly contain a Timestamp corresponding to its creation time.

The SCTP association must be established between the endpoints before any data transfer can take place. With TCP, the session is set up using a three-way message exchange between the two endpoints. One issue with TCP session setup is that it is vulnerable to so called SYN flooding

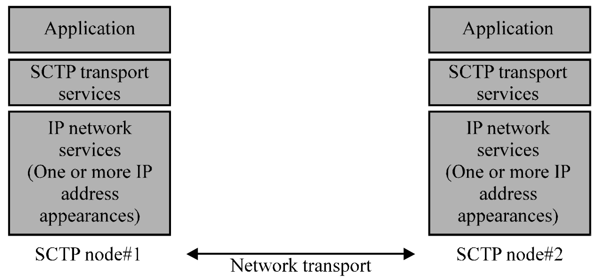

Fig. 7: SCTP association

attacks that may cause the TCP server to overload. SCTP has solved this problem by using a four-way message exchange for the association setup, including the use of a special 'cookie' that identifies the association. This makes the SCTP association setup somewhat more complex but brings additional robustness against these types of attacks. An SCTP association as well as the position of SCTP in the protocol stack is illustrated in Fig. 7.

As is also indicated in the figure, an SCTP association may be utilizing multiple IP addresses at each endpoint (this aspect is further elaborated below). Similar to TCP, SCTP is rate adaptive. This means that it will decrease or increase the data transfer rate dynamically, for example, depending on the congestion conditions in the network. The mechanisms for rate adaptation of a SCTP session are designed to behave cooperatively with TCP sessions attempting to use the same bandwidth (Olsson *et al*., 2009).

SCTP solves this by implementing a multi-streaming feature (the name Stream Control Transmission Protocol comes from this feature). This feature allows data to be divided into multiple streams that can be delivered with independent message sequence control. A message loss in one stream will then only impact the stream where the message loss occurred (at least initially) while all other streams could continue to flow. The streams are delivered within the same SCTP association and are thus subject to the same rate and congestion control. The employment of SCTP over LTE-Advanced, the two nodes negotiate the maximum number of streams that will be used over that association. However, multiple pairs of streams are typically used in order to avoid the head-of-line blocking issue. Among these pairs of streams, one must be reserved by the two nodes for the signaling of the common procedures (that is, those that are not specific to one (UE). The other streams are used for the sole purpose of the dedicated procedures (that is, those that are specific to one (UE).

CONCLUSION

This study defines the features providing by SCTP and gives an illustration to employing SCTP over LTE-Advanced networks. Also, it's investigates the architecture and specifications of user plane protocol and control plane protocol stack of LTE-Advanced and the association setup for SCTP with S1 and X2 interfaces. In addition, some differences between SCTP, TCP and UDP performance explained in this article. SCTP has been considered to be flexible and offer practical defaults for applications used by next generation systems. For applications that requisite additional control, SCTP offers a extensive host of socket choices and a multitude of assembling options. Generally, SCTP can be used instead of TCP and gives the application better flexibility. SCTP may also be used in cases where one might consider UDP, assuming a full featured employment of SCTP counting Partial Reliability.

REFERENCES

Abed, G.A., M. Ismail and K. Jumari, 2011a. Appraisal of long term evolution system with diversified TCP's. Proceedings of the 5th Asia Modelling Symposium (AMS), May 24-26, 2011, Kuala Lumpur, pp: 236-239.

Abed, G.A., M. Ismail and K. Jumari, 2011b. Traffic modeling of LTE mobile broadband network based on NS-2 simulator. Proceedings of the 3rd International Conference on Computational Intelligence, Communication Systems and Networks, July 26-28, 2011, Bali, pp: 120-125.

Akyildiz, I.F., D.M. Gutierrez-Estevez and E.C. Reyes, 2010. The evolution to 4G cellular systems: LTE-Advanced. Phys. Commun., 3: 217-244.

Alcatel-Lucent, 2009. The LTE network architecture: A comprehensive tutorial. Strategic White Paper. Alcatel-Lucent, France, pp: 1-26.

Ghosh, A., J. Zhang, R. Muhamed and J.G. Andrews, 2010. Fundamentals of LTE. Prentice Hall, USA., ISBN 0137033117, pages: 464.

Kaaranen, H., 2005. UMTS Networks: Architecture, Mobility and Services. John Wiley and Sons, New York, Pages: 406.

Khan, F., 2009. LTE for 4G mobile broadband: Air Interface Technologies and Performance. Cambridge University Press, USA., ISBN 0521882214, pages: 492.

Kiiski, M., 2010. LTE-Advanced: The mainstream in mobile broadband evolution. Proceeding of the Wireless Conference (EW), 2010 European, April 12-15, 2010, Lucca, pp: 983-988.

Kottkamp, M., 2010. LTE-Advanced technology introduction: White paper. Rohde and Schwarz, pp: 1-23. http://www2.rohde-schwarz.com/file_13924/1MA169_2E.pdf.

Lescuyer, P. and T. Lucidarme, 2008. Evolved Packet System (EPS). The LTE and SAE Evolution of 3G UMTS. John Wiley and Sons, Inc., USA., ISBN: 978-0-470-05976-0, Pages: 353.

Nam, Y.H., L. Liu, Y. Wang, C. Zhang, J. Cho and J.K. Han, 2010. Cooperative communication technologies for LTE-advanced. Proceedings of IEEE International Conference on Acoustic Speech and Signal Processing, March 14-19, Dallas, US, pp: 5610-5613.

Olsson, M., S. Sultana, S. Rommer, L. Frid and C. Mulligan, 2009. SAE and the Evolved Packet Core: Driving the Mobile Broadband Revolution. Academic Press Inc., UK., Pages: 440.

Stencel, V., A. Muller and P. Frank, 2010. LTE advanced: A further evolutionary step for next generation mobile networks. Proceedings of the 20th International Conference on Radioelektronika (Radioelektronika), April 19-21, 2010, IEEE., pp: 1-5.

Stewart, R., M. Tuxen and P. Lei, 2008. SCTP: What is it and how to use it? http://www.bsdcan.org/2008/schedule/attachments/44_bsdcan_sctp.pdf

Stewart, R., Q. Xie, K. Morneault, C. Sharp and H. Schwarzbauer *et al.*, 2000. Request for Comments: 2960. Stream control transmission protocol. Network Working Group. The Internet Society, http://www.ietf.org/rfc/rfc2960.txt.

Tapia, P., J. Liu, Y. Karimli and M.J. Feuerstein, 2009. HSPA Performance And Evolution: A Practical Perspective. John Wiley and Sons, Inc., USA.

Welzl, M., 2005. Network Congestion Control: Managing Internet Traffic. John Wiley and Sons, Chichester, UK., ISBN-13: 9780470025284, Pages: 263.