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Bandwidth Aggregation through Concurrent Multipath Transfer of Data in Wireless Networks: A Survey

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ABSTRACT: Next generation wireless communication networks are featured with heterogeneity where multiple wireless technologies exist together. In the intersection of coverage areas of these different technologies, receiver having multiple interfaces can access them concurrently so as to improve the performance and this prompts bandwidth aggregation. A larger logical link can be created by aggregating low bandwidth links. The same link can be used by a multimode terminal for applications that are demanding high-bandwidth. Advantages of bandwidth aggregation and the challenges that are faced in attaining bandwidth aggregation are discussed in this paper. An overview of the architecture, different approaches and bandwidth aggregation techniques employed in various layers of network are highlighted.

KEYWORDS: Bandwidth aggregation; concurrent multi path transfer; heterogeneous wireless network

I. INTRODUCTION

With the rapid growth of Internet, the advancement of technology and reduced cost of electronic components, more and more number of users are using the mobile data access and data transfer by using various network interfaces for the devices like laptop, notebook, tablet and smart-phone using various wireless technologies like 802.11, Bluetooth, GSM,3G, WiMax etc.[17][18] The existing wireless technologies differ in terms of services provided like bandwidth, coverage, price, quality of service support. If there is a restriction on the usage of these available resources with interfaces on the user device as one interface at a time, then imposes limitation on the flexibility and better utilization. So by using multiple interfaces simultaneously, can improve quality and provide support for applications requiring high bandwidth [18]. Further delay can be reduced when alternate path of communications are kept alive enhancing the reliability of data. Heterogeneous Wireless Network (HWN) is a wireless communication network where Internet services can be accessed through multiple wireless technologies like WiFi, WiMAX, GSM etc[5][6][9]. Nowadays many of the Internet applications are demanding high bandwidth. The bandwidth of an individual technology is not sufficient to meet the current demand. Hence by aggregating the individual low bandwidth links, form a high speedy larger logical link. Bandwidth aggregation in heterogeneous wireless network will provide many of benefits for real time applications.

II. OVERVIEW

The bandwidth aggregation in wireless networks can be defined as the aggregation of bandwidth offered by individual links of multiple technologies to form a high speedy larger logical link. The accumulated bandwidth from multiple wireless interfaces can create a high bandwidth larger logical link. This has several performance benefits [1][15] as described below.

- **Increased throughput:**
  Many internet applications like video streaming services (example: YouTube, teleconferencing, online gaming etc) demand high bandwidth. The bandwidth of existing individual technologies is inadequate to support throughput demanding video applications. Hence bandwidth aggregation provides the increased transmission throughput to meet the requirement.

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- **Resource sharing:**
  A multimode device can use various wireless technologies simultaneously to provide different range of bandwidths and each technology is being operated independently. Thus bandwidth aggregation increases resource sharing by integration of the limited channel resources available.
- **Reliability:**
  Attaining bandwidth aggregation through concurrent multipath transfer of data provides greater reliability. Multiple paths or channels are available for the transmission. At any instance, if any path fails, then there is availability of other path for the transmission. Thus bandwidth aggregation can bring in increase in reliability of communication system.

III. CHALLENGES IN BANDWIDTH AGGREGATION

The aggregated bandwidth can bring in significant benefits in the form of increased throughput, resource sharing and increased reliability as discussed in section I. However there are some challenges that need to be addressed while attaining the bandwidth aggregation. The challenges that are faced are: Packet reordering, delay and more battery power consumption.

Packet reordering:
In heterogeneous wireless networks, the packet reordering is caused due to simultaneous transmission of packets across concurrent multi paths. Each of the paths has different end-to-end delays and transmission speed resulting into arrival of packets at the receiver as out of the intended order. The reordering of the packets affects adversely on performance of any real time application.
Packet reordering occurs when the order of the packets received by the receiver is not same as the order of the packets sent by the sender [9]. That is, the sequence of the packet which is arriving is lower than the sequence of the packet that has already arrived at receiver as illustrated in fig 1. That is packet no2 is arriving after packet no 3. Similarly packet no 4 is arriving later to packet no 5. Out of order packets need to be reordered.

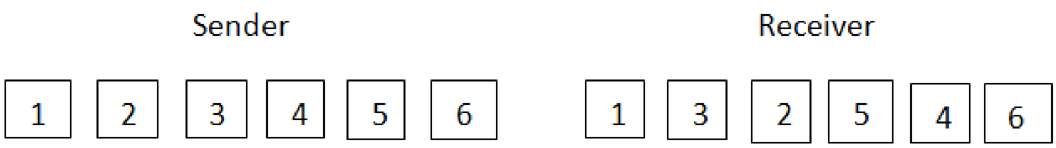

Fig 1: Packet Reordering

Delay:
The end-to-end delay is increased due to the time consumed in reordering of the packets. Due to this delay, some of the packets of real time applications miss their corresponding deadlines and get discarded. Packet reordering and the delay caused by it can also affect the Transmission Control Protocol (TCP). TCP allows reordering of packets by maximum of two positions of reordering and corrects by inbuilt re-sequencing mechanism [21]. However beyond two positions of reordering is regarded as packet loss and thus reducing the transmission window size. Consequently the application throughput may drop rapidly leading to the underutilization of accumulated bandwidth capacity. This affects a lot to the video streaming applications that have stringent quality of service (QoS) requirements. Thus for an efficient bandwidth aggregation, it is a must to incorporate the mechanism for packet reordering and minimizing the delay caused due to it.

More battery power consumption:
Battery power consumption is always a key issue with handheld devices. More amount of power is consumed by handheld devices during its operation as well as at idle periods. The battery power consumption is increased more when a terminal is equipped with multiple wireless interfaces. The operational lifetime of terminal is reduced leading to the risk of premature transmission termination. For ensuring uninterrupted concurrent multipath transfer of data, it is a must to incorporate a mechanism for minimizing the terminal's battery power consumption.

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IV. ARCHITECTURE

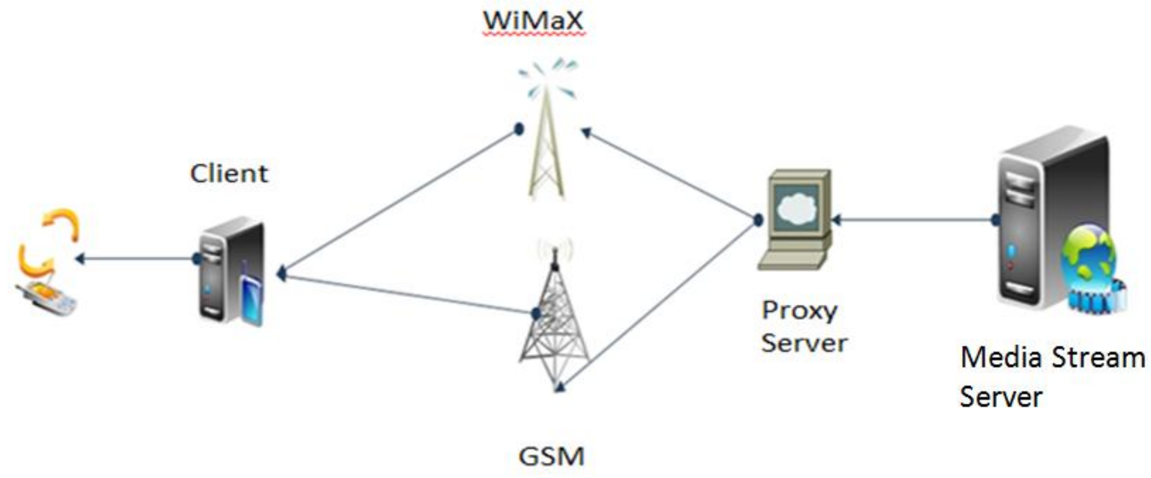

Fig 2: Overview architecture to support bandwidth aggregation

Fig 2 shows high-level overview of architecture to support bandwidth aggregation through concurrent multipath transfer. The figure depicts heterogeneous wireless network with two wireless interfaces say (WiMax and GSM). When the coverage areas of these wireless technologies overlap, a multimode device in this area can use them simultaneously [15]. When a client requests for a media stream, proxy server fetches it from Media stream server. A proxy server is connected to multiple paths in network. Each path in network is independent and has specific transmission speed being characterized by following properties [1].

- The available bandwidth – the number of bits transferred in unit time
- The round trip time – the total amount of time for sending the data packet and the time for receiving the acknowledgement of that packet
- The path loss rate – the probability that the packet gets lost in that path

Based on the above mentioned factors, transmission capacity for each path is assigned so as to obtain a total optimum throughput. However end-to-end delay of each path varies. While transferring of packets in concurrent multipath, there are more chances of packets arriving as out of order. Therefore the packet scheduling scheme [11] [12] [13] [15] is suggested to arrange the transmission sequence so as to minimize the delay caused due to reordering of packets at the receiver. The output at the receiver is generated by reordering of packets received through multi paths. This not only aggregates the available bandwidth of multi paths, but also reduces the delay due to reordering of packets at the receiver.

V. BANDWIDTH AGGREGATION APPROACHES

Bandwidth aggregation approaches are classified as dynamic or static depending on their adaptivity to network traffic flow as shown in fig 3.

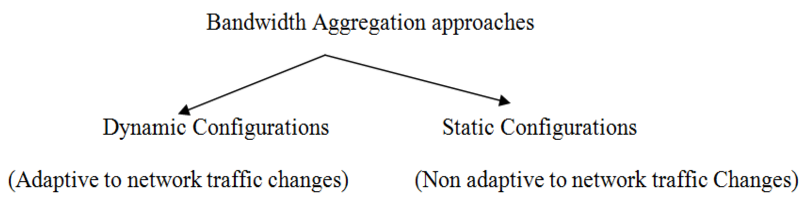

Fig3: Classification of Bandwidth aggregation approaches

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Dynamic Configuration / Adaptive approach:

The bandwidth aggregation approach in which the varying network traffic characteristics are considered are known to be dynamic configurations or adaptive approach [4]. The network traffic is characterized by available bandwidth, delay and path loss rate. These are considered periodically for making scheduling decision of packets. Adaptive bandwidth aggregation approach have better performance gains over Non-adaptive bandwidth aggregation as changes in network traffic are considered and dynamic configuration of interface selection is carried out.

Static Configuration / Non adaptive approach:

The bandwidth aggregation approaches in which the network dynamics are not considered and assume non-varying network traffic are known to be static configuration approach or non adaptive approach. The scheduling decision of packets is done based on static load balancing and does not take into consideration about network traffic conditions. Implementation of such approaches is easier and contributes for improved throughput and reliability. However performance degrades when paths have different network traffic conditions.

VI. RELATED WORK

A survey of bandwidth aggregation solutions addressed at various layers of network protocol stack such as Application layer, Transport layer, Network layer and Link layer is discussed in [4]. Here is a brief look at bandwidth aggregation techniques employed in various layers of network.

A. Application Layer:

An application layer protocol for bandwidth aggregation in mobile devices is suggested in [2]. In this paper, a protocol for aggregating WiFi and 3G wireless links on mobile devices is suggested. An algorithm is proposed that can transfer wireless data over both WiFi and 3G interfaces with the aim of minimum battery energy consumption. This service is made simple by providing a mobile application in the mobile devices that is independent of operating system and network protocol stack. In general, application layer bandwidth aggregation mechanism use a middleware for sending packets over multiple interfaces at sender as well as for collecting the received packets in proper sequence at receiver side. Thus a middleware mechanism to be deployed at both sender and receiver side for optimal operation, this limits the widespread uses of application layer bandwidth aggregation approach.

B. Transport Layer:

Stream Control Transmission Protocol (SCTP) is the standard protocol at transport layer of network to enable concurrent multipath transfer (CMT) in heterogeneous access network. A distortion aware CMT solution (CMT-DA) for video streaming is provided in [1]. The CMT-DA solution uses estimating path status, allocating flow rate also delay and loss controlled retransmission to have quality of service (QoS) in real time video streaming in multiple wireless interfaces [14]. In this paper, transmission of video streaming is done using the SCTP association [7] from source to a destination node. SCTP transmission involves the sockets. [10] The video is encoded and further encoded data is then divided into several chunks and sent over multipaths. The receiver receives the packets in a receiving buffer and reorders to restore the original video to be given to the upper layer applications. The transport layer mechanisms for bandwidth aggregation require adaptations at node as well as remote server, this limits deployment to specific applications.

C. Network Layer:

An important aspect of bandwidth aggregation mechanism is scheduling of data packets onto different interfaces. A network layer solution for bandwidth aggregation is given by proposing a well known Earliest Delivery Path First (EDPF) scheduling algorithm [15]. A packet-pair scheduling for TCP application was also proposed [17]. Both the approaches involve a network proxy, providing various services like bandwidth aggregation, resource sharing and mobility support to client by accessing multiple network interfaces. Network proxy is responsible for concurrent transmission of data over multi paths and also assembling the packets received at receiver. A mobile

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host (MH) connected to network via multiple interfaces acquires a fixed IP address from network proxy and uses it to directly communicate with the remote server. The network proxy works based on IP-within-IP encapsulation. This mechanism is similar to the mechanism used in Mobile – IP, but with extension to support multiple interfaces. The network layer solution overcomes the limitations of solutions provided at other layers of network but is always not an efficient approach as it operates at lower layer of the network protocol stack.

D. **Link Layer:**

Bandwidth aggregation at link layer allows multiple data link paths to be grouped into a single larger logical path with the capacity greater than individual path's capacity. In link layer protocol, data units are split across multi paths to achieve increased throughput. A concept of Generic Link Layer (GLL) [16] offers a link layer functioning over heterogeneous wireless interfaces to have improved performance. A similar concept as Cognitive Convergence Layer (CCL) [19] which synchronizes the various functions of link layer and create a unique virtual link layer interface between upper and lower layers of network interfaces. The CCL performs traffic distribution at sender and reordering of packets at receiver. Some more link layer approaches have been proposed. [2] However, link layer bandwidth aggregation solution require specific hardware or software, this limits the deployment of this approach to local domains under the control of same operator.

VII. CONCLUSION AND FUTURE SCOPE

Bandwidth aggregation approaches are proposed so that a multimode terminal equipped with multiple network interfaces can access through concurrent multi paths [20]. Bandwidth aggregation services can bring in significant improvements in performance over conventional single interface use by providing increased throughput, resource sharing and reliability. By the aggregation of existing lower bandwidth links so as to create a larger logical link, can serve the applications demanding high bandwidth. This paper presents a survey of bandwidth aggregation approaches developed to have concurrent multipath transfer across multiple wireless technologies simultaneously. In future, the wireless communication networks would be the convergent of various access networks, incorporating diverse transmission features and capabilities. Bandwidth aggregation is facilitated in multihomed mobile terminals for increased transmission throughput and enhanced reliability.

REFERENCES

1. Jiyan Wu, Bo Cheng,Chau Yuen, Yanlei Shang, and Junliang Chen "Distortion-Aware Concurrent Multipath Transferfor Mobile Video Streaming in Heterogeneous Wireless Networks" IEEE TRANSACTIONS ON MOBILE COMPUTING, VOL. 14, NO. 4, APRIL 2015
2. Swaminathan Seetharaman, Dr. S. Srikanth "Integrated approach towards Bandwidth Aggregation (BAG) in multi-homed devices", 3rd International Conference on Signal Processing, Communication and Networking (ICSCN) 2015
3. Zaiyang Tang, Zirui Wang, Peng Li, Song Guo, Xiaofei Liao, and Hai Jin "An Application Layer Protocol forEnergy-Efficient Bandwidth Aggregation with Guaranteed Quality-of-Experience", IEEE Transactions on Parallel and Distributed Systems2014
4. Allen L. Ramaboli n, Olabisi E.Falowo, Anthony H.Chan "Bandwidth aggregation in heterogeneous wireless networks: A survey of current approaches and issues" Journal of Network and Computer Applications 35 (2012) 1674–1690
5. M. H. Masud, S. A. LatifF. Anwar M. K. Alam"A Scheduling Algorithm for Bandwidth Aggregation in Heterogeneous Wireless Network", 3rd INTERNATIONAL CONFERENCE ON INFORMATICS, ELECTRONICS & VISION 2014
6. Ze Li and Haiying Shen"A QoS-Oriented Distributed Routing Protocol for Hybrid Wireless Networks", IEEE TRANSACTIONS ON MOBILE COMPUTING, VOL. 13, NO. 3, MARCH 2014
7. Mohammad Mamun Elahi, Shahin Khan" A Distributed SCTP Scheme for Bandwidth aggregation"16th Int'l Conference of Computer and Information Technology, 8-10 March 2014
8. Changqiao Xu, Zhuofeng Li, Jinglin Li, Hongke Zhang and Gabriel-MiroMuntean, "Cross-layer Fairness-driven Concurrent Multipath Video Delivery over Heterogeneous Wireless Networks" IEEE Transactions on Circuits and Systems for Video Technology 2013
9. Suhaimi A. Latif, Mosharrof H. Masud, Farhat Anwar and Md. Khorshed Alam, "An Investigation of Scheduling and Packet Reordering Algorithms for Bandwidth Aggregation in Heterogeneous Wireless Networks", Middle-East Journal of Scientific Research 2013
10. Jiyan Wu, Jingqi Yang, and Junliang Chen "Loss Tolerant Bandwidth Aggregation for Multihomed Video Streaming over Heterogeneous Wireless Networks" Globecom 2013-Symposium
11. KanZheng,Fei Liu, WeiXiang, Xuemei Xin "Dynamic downlink aggregation carrier scheduling scheme for wireless networks."Published in IETCommunicationsDOI:10.1049/iet-com,2013.
12. Karim Habak, Moustafa Youssef and Khaled A. Harras., "An optimal deployable bandwidth aggregation system", Computer Networks Elsevier (2013).

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

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13. D. Krishnaswamy, D. Zhang, D. Cavendish, S. Soliman, B. Mohanty, S. Eravelli"COBA: Concurrent Bandwidth Aggregation - a case study in Parallel Wireless Communications" Journal of Communications, Special issue on Future directions on computing and networking, Vol 7 , 2012
14. Juan Carlos Fernandez, TarikTaleb, Mohsen Guizani, Nei Kato "Bandwidth Aggregation-Aware Dynamic QoS Negotiation for Real-Time Video Streamingin Next-Generation Wireless Networks" IEEE TRANSACTIONS ON MULTIMEDIA, VOL. 11, NO. 6, OCTOBER 2009
15. Kameswari Chebrolu andRamesh R.Rao"Bandwidth Aggregation for Real-Time Applications in Heterogeneous Wireless Networks" IEEE Transactions On Mobile Computing, VOL.5, NO. 4, 2006
16. Koudouridis GP,Aguero R, AlexandriE, ChoqueJ, DimouK,KarimiHR, LedererH, Sachs J, SigleR, "Generic link layer functionality for multiradio access networks". In Proceedings ofmobile summit, 2005.
17. Kameswari Chebrolu, Bhaskaran Raman, Ramesh R. Rao. "ANetwork Layer Approach to Enable TCP over Multiple Interfaces", Wireless Networks Journal, Volume 11 Issue 5, September 2005, pp.637-650.
18. Karim Habak, Khaled A. Harras, and Moustafa Youssef, "OSCAR: A Collaborative Bandwidth Aggregation System", ArXive: 1401.1258.
19. Kim J-O, Ueda T, Obana S. MAC-level measurement based traffic distribution over IEEE 802.11 multi-radio networks. IEEE Transactions on Consumer Electronics 2008;54(3):1185–91.
20. Manousakis, K., Gopalakrishnan, P., Famolari, D., and van den Berg,E., "INTELiCON: Intelligent connectivity Framework for the Simultaneous Use of Multiple Interfaces", IEEE International Conference on Communications (ICC '07), June 2007.
21. Przybylski M, Belter B, Binczewski A. Shall we worry about packet reordering. Computational Methods in Science and Technology 2005;11(2):141–6.