TOWARDS A POWER CONSUMPTION ESTIMATION MODEL FOR ROUTERS OVER TCP AND UDP PROTOCOLS

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Abstract

Due to the growing development in the information and communication technology (ICT) industry, the usage of routers has increased rapidly. Meanwhile, these devices that are produced and developed today consume a definite amount of power, Furthermore, with limited focus on power estimation techniques and the increased demands of networking devices, it led to an increase of the vitality consumption as a result. While new high capacity router components are installed, energy intake in system elements will be rising due to the higher capability network consuming larger component of the vitality. This study considers providing estimating power model in different traffic settings over TCP and UDP protocols, this study is mainly concerned about the transport protocols power consumption. Isolating the power consuming components within an electronic system is a very precise process that requires deep understanding of the role of each component within the system and a thorough study of the component datasheet. The study started by simulating the protocols mechanism then followed by protoclos power measurements, a simple simulation has been provided for Xilinx Virtex-5, it is very complicated to simulate the whole system due to the need of an external devices, so the simulation focused on wavelengths, fequencies and traficc types. This study found that the estimated power stokes was high when the 1480nm, 1580nm, and 1750nm power source increase.while there were diferrence in the consumed power while trasiting different types of traffic such as CBR and HTTP throug UDP and TCP. The effect of different frequencies has been noticed also while applying different frequencies to the protocols. So it is believed that this study may enhance the power scenarios in the netwrok and routers throug applying different techniques to UDP and TCP.

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To my extended family in Iraq, a special thanks and dedication go to my beloved wife, whom passed away and left me hopeless, she was the one who always supporting me whenever I needed and supported me in every critical situation I have faced, after her funeral, I decided to give up and leave my study but my beloved father, and my beloved mother kept encouraging, supporting and praying for me. Thanks to my father for his faith and wisdom, to my mother for her soft heart and genuine love, to my sisters and their husbands for their unlimited support.

To everyone stood by my side and advised, inspired and encouraged me. For the person who asked me to look at the glass half full and to live life with no regrets. Thanks to my clever and brave son (Alhassan), in spite of his age is only 2 and half years but he did support for me more than anyone.

I would like also to extend my thanks and appreciation to all of my friends who have contributed in one way or another to help me complete this thesis successfully. Last, but not least, special thanks for everyone helped me in completing this thesis and challenging journey successfully.

Ali Qusay Mohammed

UUM, Sintok, June, 2015

Dedicated to the soul of my wife

To my parents, my sisters and my son

Ali Qusay
25th June 2015

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List of Abbreviations

ARP	Adress Resolution Protocol
ARPNET	Advanced Research Projects Agency Network
CBR	Constant Bit Rate
DC	Direct Current
DVFS	Dynamic Voltage Frequency Scaling
FPGA	Field Programmable Gate Array
HDL	Hardware Description Language
HTTP	Hyper Text Transfer Protocol
ICT	Information and Communications Technology
IP	Internet Protocol
IT	Information Technology
LAN	Local Area Network
NOC	Network On Chip

RF	Radio Frequency
RPAR	Real-time Power Aware Routing
SSL	Secure Socket Layer
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VHSIC	Very High Speed Integrated Ciruit
WLAN	Wireless Local Arean Network

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Energy consumption and estimation are important aspects that drive the technology development nowadays (Sen, 2012; Trivailo, Sippel, & Şekercioğlu, 2012). With the evolution in computer hardware design and manufacturing, the circuit demand for energy has continuously risen and is also crucial for the continued development (Pocek, Tessier, & DeHon, 2013). This was reasoned by some researcher as the need for extending the circuit capacity due to heavy traffic demands which in turn result in more power consumption (Aymerich & Rubio, 2013; McGinnis, 2014). On the other hand, almost all router devices that are produced and developed today consume a definite amount of power (Kirschbaum & Plos, 2014; C. A. Lee, Gasster, Plaza, Chang, & Huang, 2011). Due to the growing development in the information and communication technology (ICT) industry, the usage of these devices has increased rapidly. Consequently, power is being consumed at an ever increasing rate (C. A. Lee et al., 2011). Unfortunately, this trend is also producing adverse effects on circuit capability to effectively estimate power consumption and also result to undesired heating effects. Thus, power consumption estimation techniques can provide the alternative the opportunity to balance power consumption in routers.

With the transport covering, when it involves handling power related efficiency and also necessary retransmissions, problems might rise if one or more intermediated back links are resulted from error prone. To ease the dilemma, several approaches are proposed. Protocol optimizations attempts are made for reducing the power consumption involving wireless LAN interfaces, good observation that will, the move protocol, which tools flow control to modify the system traffic in router related settings. Network interface vibrant power operations, reduces electric power by supervising run-time parameters inside the transport protocol, coarse-granularity nonproductive periods. It has been shown that will error effects degrade electricity performance involving Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) (Xylomenos & Polyzos, 1999). Ever since then, several tries have tried to further improve the electricity efficiency involving TCP. TCP might be made alert to non-congestion-related failures, improving the two performance and also energy. Techniques used for this purpose are nearby retransmissions, split connections, and extra forward error correction. Power-aware TCP could also be used to create the sender transmit in the predictable fashion (Bansal, Shorey, & Kherani, 2004). By creating the sender transfer data throughout bursts along with sufficient separation together, the phone is provided the means to settle the nonproductive periods.

Furthermore, with limited focus on power estimation techniques and the increased demands of networking devices, it led to an increase of the vitality consumption as a result (Fodor et al., 2012).

While using the router devices in heavy traffic along with the connectivity factor to different applications and devices, the amount of traffic flowing from the Internet provides dramatically elevated (Niknam, Golestaneh, & Malekpour, 2012). Therefore, power consumption required for routing as well as processing traffic may be growing accordingly. Since Internet protocol (IP) traffic is escalating rapidly, estimating the power needs necessary to route must match the application needs (Wang, Yao, Wang, Lu, & Cao, 2012). It led for the increment in amount of the ICT devices including routers and hubs. As such, there is a growth within power estimation of these devices. This enhance in energy consumption is becoming a main barrier within continued bandwidth scaling with the Internet (Siano, Cecati, Yu, & Kolbusz, 2012). And it also has raised the challenge of perhaps the Internet may ultimately end up being constrained not with the speed connected with routers, switches and also other electronics devices but alternatively by their power usage and energy efficiency.

While new high capacity router components are installed, energy intake in system elements will be rising due to the higher capability network consuming larger component of the vitality (Lange et al., 2014). The researcher in this study considers power operations for networks from the perspective of the mentioned power saving consumption and providing estimation model based on TCP and UDP protocols. This motivation was also driven by the constant concern the power consumption of different system elements (Khazaii, 2014; Lazaris, 2012). The attempt of getting energy understanding in system elements as well as processes is frequently referred to as green networking. Also the power intake and heat dissipation inside the circuit led router manufactory to design the circuit by chopping the energy balance components without considering the application and traffic associated with (Tabataba, Sadeghi, Hucher, & Pakravan, 2012). The response from this concerns has become not merely to improve the particular hardware consumption but additionally to find techniques to design as well as operate networks in a more vitality efficient way. Design power estimation models have mainly concerns about the datasheet given by the providers to suite a definite usage (Landsiedel, Ghadimi, Duquennoy, & Johansson, 2012b; Pfluger & Feist, 2013). Even so, recently there is an increasing quantity of energy -aware system design as well as operational techniques aiming on reducing ICT vitality consumption, the need for efficient power consumption estimation models is still needed.

1.2 Research Background

Understanding every detail about how and where power is consumed within a certain system is very critical in order to find methods of optimizing the use of this consumed power (Bouhafs, Mackay, & Merabti, 2012; Wood & Wollenberg, 2012), for example in integrated circuits and electronic systems, there are two types of power, static power and dynamic power, static power is the power consumed by a chip while it is in standby status where no operations are undergone involving that chip (H. Wang, Liserre, & Blaabjerg, 2013), while dynamic power is the power consumed during processing when the chip is involved in logic operations that requires changes of logic at every stage of the electronic system within the chip (Rotem, Naveh, Ananthakrishnan, Rajwan, & Weissmann, 2012).

Typically static power is almost constant whether the chip is in standby mode or in operating mode, however dynamic power changes dramatically when the chip operates (Schlottmann, Shapero, Nease, & Hasler, 2012). This power is typically proportional to the operating frequency of the digital chip, but sometimes linearity is not perfect due to the fact that the resistance of chip components change when the temperature changes, which means that the higher the operating frequency (Dargie, 2012), the higher the chip temperature which finally affects the resistance of each component leading to some non-linearity between the dynamic power and the operating frequency.

There are components with negligible power consumption but passive components maybe more complicated from this aspect since you need to understand the role of the passive component before you decide whether power calculation over this component is negligible or not (David, Bogdan, Marculescu, & Ogras, 2011). Modern electronics are being designed based on portability and low power consumption. Digital processing systems can be integrated in many different portable devices. In each situation the power consumption is essential to the functionality of the system, not only because the battery duration depends on it, but also because of the heating problems that arise.

The current techniques for estimating power stability need to provide a stipulate result which involves digital control systems (Lehn & Irvani, 1999). Parameters that define power estimation are categorized into hardware and software. Power parameters for hardware related systems relies on the consumption of chip itself in which other factors such as memories, transmission quests and many others effects consumption estimation. However, power optimization can also occur by means of software reprogramming for a definite hardware devices (Wu, Moslehi, & Bose, 2005).

In routers, the substitute involving total workouts by means of identical estimation parameters which produce exactly the same computational result of various energy actions that can certainly contribute to the ability optimization of the system (Vasseur, Kim, Pister, Dejean, & Barthel, 2011). As such, energy evaluation is crucial and also shows being helpful in all the feasible ways to improve the digital systems, including simulation, hardware partitioning and software reprogramming.

1.3 Problem Statement

In today's Internet, a significant fraction of the energy consumed by network devices is wasted, because no or very little proportionality exists between energy consumption and device utilization; in other words, the energy consumption of network devices is today largely independent of the carried traffic.

When working with digital chips, one must discriminate between what is negligible and what's not, for example, the static/standby power in any chip is usually negligible compared to dynamic power consumption during real processing, besides dynamic power is not always linear with operating frequency due to the fact that resistance changes with higher power emissions at higher operating frequencies leading to non linear power consumption versus frequency.

Isolating the power consuming components within an electronic system is a very precise process that requires deep understanding of the role of each component within the system and a thorough study of the component datasheet (De Rango, Guerriero, & Fazio, 2012). Bansal et al. (2004) stated that achieving a reliable power efficiency along with data transmitting over TCP and UDP is challenging in which it consumes significant amount of power in order to perform multiple operations. The sustainability of the Internet strongly and clearly relies on the efficiency of technologies and protocols working at the network edge, and more specifically inside networked devices while the network protocol and its implementation need to be optimized as much as possible (Bolla, Bruschi, Davoli, & Cucchietti, 2011).

Since routers are communications equipment, they require several voltage regulators to provide for the right voltage supply for each chip. However, each regulator consumes power that is typically non-linear (Vasseur et al., 2011) to the consumed power which makes regulator one of the most difficult components within an electronic system, since the need to define its output current before considering the efficiency curve to see how much power it consume, and how much power it really delivers(Woo, Tong, & Culler, 2003). Therefore, this study is established to provide optimal calculation models for two routing protocols based on two types of traffic, different wavelengths, and different frequencies.

1.4 Research Questions

This study aims at answering the following research questions:

1. How to prove that different wavelengths have an effect on power consumptions for TCP and UDP protocols?
2. How to simulate power consumption for TCP and UDP protocols based on provided traffic type?
3. What is the relationship between TCP and UDP frequencies with their power consumption values?

1.5 Research Objectives

By aligning to the research questions, this section provides the suggested soultions for the research problem. Besically there are three objectives for this research work as below:

1. To explore wether different wavelengths have any effect on TCP and UDP protocols power consumption.
2. To simulate the power consumption of UDP protocol based one CBR traffic and TCP based on HTTP traffic.
3. To find out the relationship among TCP and UDP different frequencies with estimated power consumption .

1.6 Research Scope

With such work, it was necessary for the reasercher to focus on TCP and UDP protocols. For TCP, we focused on Hyper Text Transfer Protocol (HTTP) traffic which basically flows into TCP throuout Secure Sockets Layer (SSL) as shown in figure 1.1.

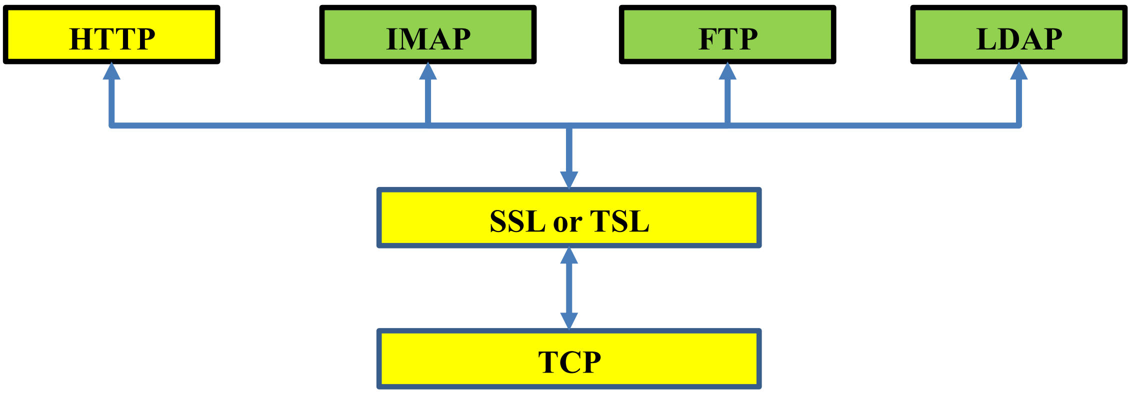

Figure 1.1: TCP versus HTTP scope

While for UDP we focused on Constant Bit Rate (CBR) traffic which reachs to the Internet through UDP as shown in the figure 1.2.

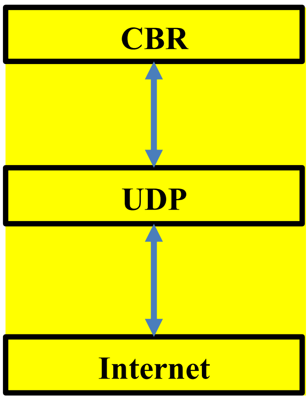

Figure 1.2: UDP versus CBR scope

For the simulation, the researcher in this study used Very High Speed Integrated Cuircit (VHSIC) Hardware Description Language (VHLD) as a hardware description language in order to stimulate the proposed power estimation model over TCP and UDP protocols. This language help integrate binary aspects with different power level. As such, it was believed that such utilization can help provide a clearer view about the applicability of power estimation in router. The default settings for both protocols were considered for simulation related purposes. Meanwhile, Xilinx Vivado Vertex-5 was used as a simulation software, because it delivers robust performance and low power with predictable results which minimum usage of memory, at the same time it gives chance to improve the work by simulating or re-programming it on the digital re-programmable devices.

1.7 Research Significance

This study can offer ICT and IT industry an effective way for estimating power consumption of routering protocols in different traffic types. This includes measuring the consumed power over HTTP and CBR. Meanwhile, it also exploring the effectivness of keying in different wavelengths and frequencies on TCP and UDP protocols. Having this in mind, the present study offer adequacy and acceptable measures of power consumption estimation in different power changing sessions as discussed in Chapter 4.

1.8 Conclusion

This chapter introduced the research background associated with the importance of power saving in ICT and IT related environments. It also highlights the current issues associated with power saving of routers in two protocols, TCP and UDP based on different traffic types,wavelengths and frequencies. The problem begin studies by the researcher mainly concerns about exploring the power consumption estimation of routing protocols in different traffic types, then by comparing the simulation result for both protocols for different scenarios.

CHAPTER TWO

LITERATURE REVIEW

This chapter illustrate the main aspects related to the router power saving. This includes reviewing the current techniques of power saving for different scenarios. It also reports the configuration of routers' operation in different modes.

2.1 Introduction

One of the greatest inventions, the Internet, is still developing at an increasing rate. From the biggest companies in the industry to a simple user, the Internet has become a must have and everyone benefits from its use. Communication is still the main use of the Internet, but it has many faces now. Some of the most important protocols used in the Internet are the Internet Protocol (IP), the Transport and Control Protocol (TCP) and the User Datagram Protocol (UDP). The increased demand for Internet based services lead to new developments of hardware and software technologies. Reducing costs, increasing bandwidth are also factors in the evolution of protocols and standards, some solutions are already being deployed around the world. With this evolution comes the need for efficient software to make proper use of the powerful hardware and handle both the data and the management of these devices.

At the transport layer, when it comes to handling energy efficiency and unnecessary retransmissions, problems would rise if one or more intermediated links were error prone. To alleviate the problem, several approaches have been proposed. Protocol optimizations attempts are made for reducing the energy consumption of WLAN interfaces, based on the observation that, the transport protocol, which implements flow control to regulate the network traffic. Network interface dynamic power management, reduces power by monitoring run-time parameters in the transport protocol, coarse-granularity idle periods.

2.2 Routers

Routers defined as tools that work with network layer of the OSI reference layer which equip with the basic aim to route data among networks (Chao & Liu, 2007). Such tool can work in the computer serving two networks to support the protocol of the IP. Packets are broadcasted by interface through the network to the router (Yaling Yang, Wang, & Kravets, 2005). The router can be put on the network at any point, and it ties with two networks (Branch, Giannella, Szymanski, Wolff, & Kargupta, 2013), and it can send data to any packet regarding to the state that has connecting network. The router makes and also gives a table for the conditions of the possible routes (Patil, 2012). Before reaching the goal, the packet passes several points (Citap, 2012).

Due to the fact that routing is a way that has pockets, it needs to provide continues supply to the path from the sender. The task of getting a series of routes between the source and targeted network in the IP will get a decrement. There are two components of routers, first is forwarding engine, second is a routing engine (Fairhurst, 2001). The engine of routing is taking charge on the processing of routing information for example it is computing the path of the shortest by using proper algorithms, clearing the ‘destination, ‘next-hop interface, and a metric (Bryant et al., 2011). The most important objective of forwarding engine is to manage the transference of the incoming traffic to the goal by taking into account the information of the forwarding information base (Fairhurst, 2001). There can be integration among the intermediate systems and networks for forming a set of interconnections to use the routers.

2.3 Operation of Routers

A router table is a vital in the process of the routing, and it is used as a data that has the routes to particular network goal (Saleem, Hassan, & Buhari, 2014). It is not a big memory, and it is controlled by the router in both hardware and software (Sarkar & Paul, 2014).

At this time, measurements that are connected are additionally recorded on it. The routing table additionally provides data that related to the structure of the system beside it (Landsiedel, Ghadimi, Duquennoy, & Johansson, 2012a). Many hubs at the system do not evaluate that course may work. Rather, the IP will be sent bundle to an entryway through the LAN, that chooses the method for conveying the parcels to the obliged goal (Malkin, 1998). For getting information about delivering different data packages, each one of the gateways is using the routing table. The track of the paths and the gateway are allowed for providing information that requested (Kandula, Iyer, & Divan, 2013).

2.3.1 **Type of Destination**

There are different destinations that routers usually appeal to when forwarding IP data traffic. It is well known that network destination consists of a collection of IPs exchanged between computers (Yasudo et al., 2014). Authors in (Fall & Stevens, 2011) addressed the number of IPs classes that network usually deal with such as A, B, or C, and IP subnets in which the routing is linked to multiplexer to manage network traffic.

2.3.2 **Address Mask**

Address mark is a routing aspect that mapped within the subsets of network IPs whereas IPs at the same time deal with the address mask identifies a range of IP addresses. As such, the routing depends on address mask in identifying the traffic peak based on the IP subnets received.

2.3.3 **Interface**

The actual forwarding network consists of interface that have to be run by sending a package to the next final destination hop in which such application can be in most routing (Kazemian et al., 2013). This involves getting optimal way for forwarding the datagram or the transferred signals towards the target. Routes need to be designed in a way that could handle signal interruption in heavy traffic peak as putting the very best routing process for every single target with the system is highly needed (Dimitrakopoulos, Psarras, & Seitanidis, 2015). Consequently, for identifying the best route consumption of power, the researcher modeled a power model for calculating power estimation in different network flow in which the process of handling traffic packets is called the metric (Singh, Singh, & Sharma, 2012).

2.4 Types and Vendors of Routers

Routers can be used to establish the network connection by linking the computers to the Internet. At the office or the home wireless routers are offering to broadcasted signal, while the edge routers are located at the end of ISP network and are normally configured to external protocol like border gateway protocol (BGP) to another BGP of another Internet service provider (Thakur, 2012).

Subscriber edge router represents the end user organization and is it structured to end an external BGP and the core routers stay at the center of LAN network and interconnects the combination routers from multiple building of a LAN, or Large enterprise position (Kessler, 1999; Malkin, 1998). Relying on the power requirements and capacity, many types of routers can be obtainable from the market such as HP, D-link, Avaya, Brocade, Juniper, Linksys and Cisco. The price of the routers is very important and the performance as well for the market consumption.

2.5 Transport Protocols

In order to determine the potential of any power estimation in router related settings, the researcher explained in the following sections two protocols that are mainly found to potentially influence the power distribution and stability in routers. Therefore, it is essential to have a clear knowledge about the fundamental transport protocols of the Internet: the User Datagram Protocol (UDP) and the Transmission Control Protocol (TCP).

2.5.1 **User Datagram Protocol (UDP)**

UDP is a simple method for giving a packet of data over the router components. It permits the working computer to consider the power required for virtual port in message transmission contexts, and acknowledge the payload for packets of data which have been sent (C. Lee, Lee, & Moon, 2012). Both the peers within communication are classified as the connector plus the client side. They communicate using electronic port volumes that identify server stream status with regards to client to server communication. This could opens a new socket to the port to provide additional ports for receiving data, understanding that socket indicates it is readable whenever a packet arrives destined for that port (Rathje & Richards, 2014). UDP electrical sockets can behave in a connectionless state: when reading from socket as shown in Figure 2.1, the two packet payload plus the sender's address is going to be returned. This permits one socket to multiplex information from many other computers. (Von Werther & Röder, 2013) As such, it can be concluded that connectionless electrical sockets require the particular destination's address for everyone outgoing datagrams.

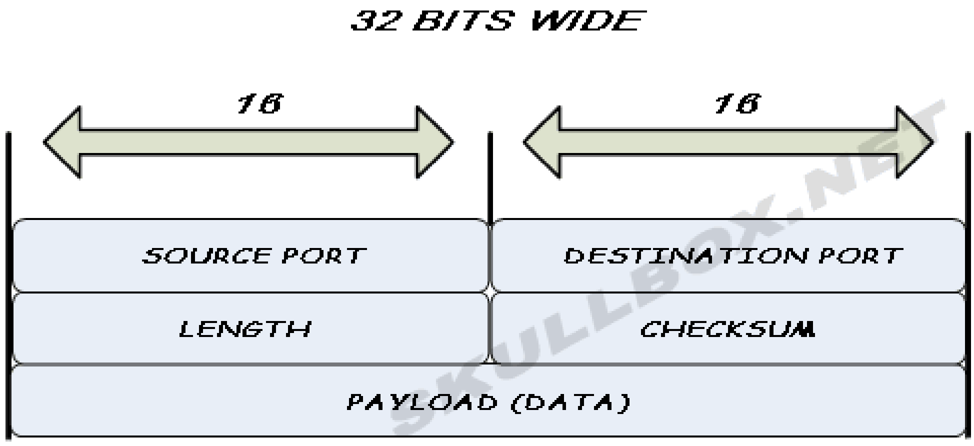

Figure 2.1: UDP structure

On the other hand, the consequences of UDP sockets can also behave while connected electrical sockets: they may reject, through an error message, all packets that have been not sent through the intended peer. When transmitting data, the other circuit components need not specify the target address: it has to be the peer to that the socket is connected (Seferoglu, Markopoulou, & Médard, 2011). Nonetheless, the Internet is a chaotic and also unpredictable asynchronous packet- transferring network. From different perspectives, it is not like circuit-switching communities (e. grams. the phone service) in which devote quite a few fixed-speed and also fixed-delay circuits, packets on the transmitted packets all over the circuit components by lots of routers cooperating to offer the packets get to their desired destination (Tuexen & Stewart, 2013). Unlike telephony, which provides a fixed bandwidth along established circuits, packet-switching communities are implemented such that they lower packets in which exceed in which current bandwidth due to congestion. Additionally, the sent out nature with the Internet tolerates failure through dynamic routing and also this leads to reordered and also duplicated packets (Almási, 2012; Dietrich, Rossow, & Pohlmann, 2013). Meanwhile, the structural representation of network elements in UDP is usually not account for these realities, and just sends buffers regarding data while datagrams for their intended desired destination; datagrams may perhaps arrive away from order, grow, or never (Manabe, Funasaka, & Ishida, 2012). The essential difference concerning UDP and also TCP is that TCP is designed for robustness from the realities regarding asynchronous packet switching distributor.

2.5.2 **Transmission Control Protocol (TCP)**

TCP is commonly known as a protocol intended to assure trusted communication through a chaotic functions of the network components which usually accounting pertaining to packet damage and reordering. It provides a simple and also elegantly intended, and inside the work of other researchers (Kong & Ren, 2014). TCP is mainly responsible for the transporting of the data. Transporting refers to reliable data transfer from one device to another and is also in charge of controlling size, flow control, rate of data exchange and network traffic congestion.

Meanwhile, TCP is usually operates in the connected wording, allowing 2 computers big to every single send any stream of data for their peer, data as such can be unable to transmit to the other components of network especially over unconnected TCP electrical sockets. The cost to maintain stable estimation of power required for TCP is significantly greater in comparison with UDP (Yi Yang et al., 2014). Mitigating the actual realities of the Internet involves larger packet headers of which communicate metadata for stream plus the state with their connection. Alternatively, aspects relevant to the dependability is realized by numbering and also acknowledging the many data that's passed over the system (Sundararajan et al., 2011); unacknowledged facts is buffered and also occasionally resent as shown in Figure 2.2.

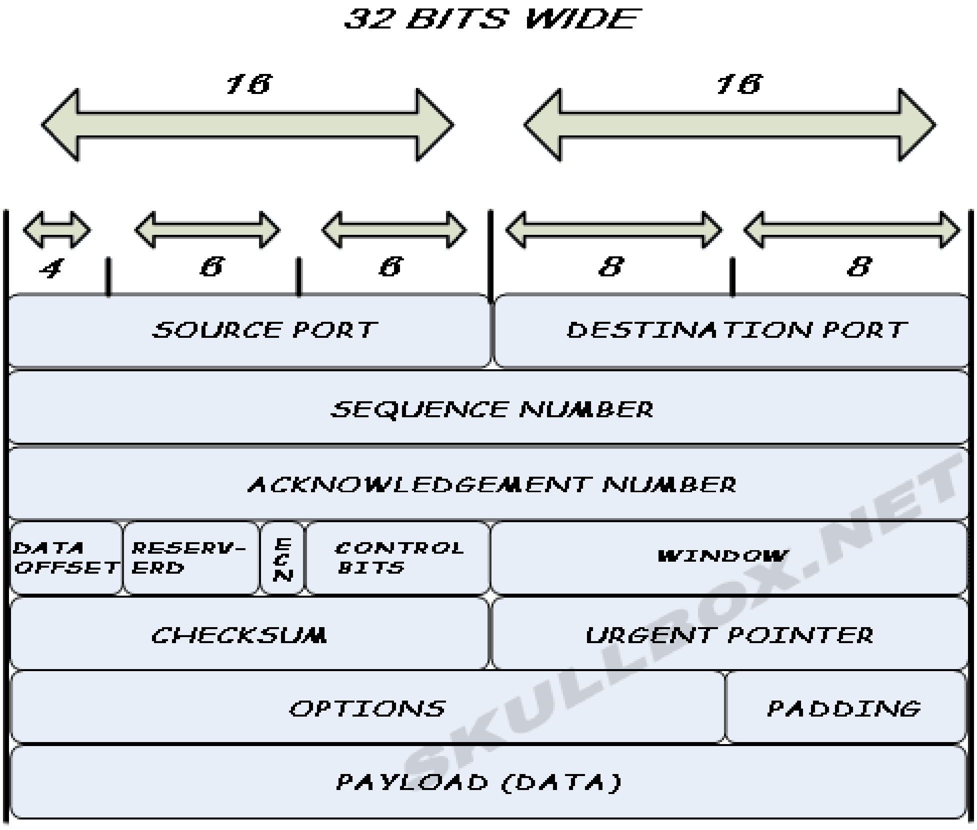

Figure 2.2: TCP structure

Having this in mind, it can be reasoned that more metrics are needed to be used for circulation control, where receivers will probably advertise the size of data they might accept in order to encourage your sender to modify their transmitting (Lixia et al., 2012). This advertised value, called the windowpane size, allows the perspective receiver to point to the target sender just how much buffer space can be acquired for new data. On the other hand, senders likewise infer congestion that occurs through the source network from the need to retransmit messages. Two algorithms, slow start as well as congestion reduction, are applied together in order to respectively cure and prevent causing congestion as shown in Figure 2.3.

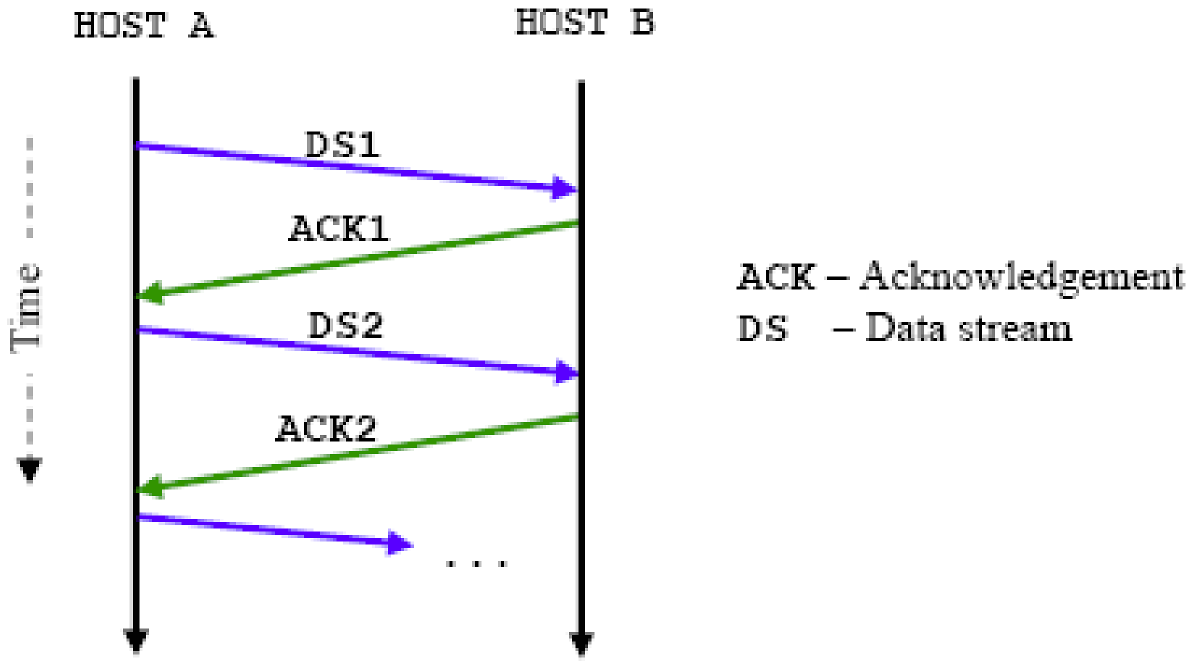

Figure 2.3: TCP working scenario

2.6 Current trends of TCP and UDP in power communication

The power estimation in routers relay heavily on the amount of power required to perform a particular transmission of data in different network peaks. Which also known as a way for providing an alternative way to transmit data towards the appropriate software process about the destination gadget, error checking out mechanisms in addition to data stream controls. TCP in addition to UDP are the renowned transport coating protocols and they are used throughout both born and instant networks (Ancillotti, Bruno, & Conti, 2014). Retransmission is the key operate of TCP that makes it a dependable transmission method. TCP additionally rearranges out-of-order packets, and even helps limit network blockage through stream control using variable-size sliding off the road windows. Nonetheless, all these types of functions incur relatively long indication delays in addition to heavy box loads (Gumenyuk, Vaskiv, & Yankevych, 2014). Having this in mind, it can be clearly shown that TCP can be optimized for accurate delivery rather than timely shipping. As in opposition to TCP's complexity, UDP can be light-weight using minimal cost and fast transmission as it not implement dependable / purchased delivery or even flow command. Real-time software that usually concerns with the use of UDP about the transport layer to its fast indication but that leaves reliability since the problem to get solved.

Delays in the control trap have harmful effects using a control method, as carry out the circle delays within a network stock it may required additional room that can be facilitated by multiplexers. Rajendran, Obraczka and Garcia, in (Rajendran, Obraczka, & Garcia-Luna-Aceves, 2006) remarked that control functionality degrades due to distributed medium access control besides the performance degradation attributable to random delays and also frame losses. Another harmful effect involving random delays within an network packet transmission sequence which is actually system destabilization. System functionality degradation simply by delays in-the-loop and how delays can reduce the stability region with the system usually are illustrated simply by Jurdak, Lopes and Baldi in (Jurdak, Lopes, & Baldi, 2004). For that reason, in order in order to avoid control functionality degradation and prevent destabilization with the control method, considerable research is usually used in order to help reduce or recompense for randomly delays and also jitter.

Jin, Zhou, Luo and Qing in (Jin, Zhou, Luo, & Qing, 2015) developed a dependable dynamic load UDP structure for the aim of enhancing the functionality of dependable UDP in the aspect involving transmission delays and also network throughput. Reliable UDP is a UDP based protocol made to guarantee your reliability involving UDP and it is elaborated in the next section (Francini, Fortune, Klein, & Ricca, 2015). The theory of dependable protocol in reducing the power estimation of circuit was studied and cited as an important way to simplify the sender pinpoints the load size that the receiver must reserve to help store the potentially disordered data before that receives the packets. In the event the buffer is actually full, the device should arrange the disordered packets and also submit the crooks to the upper layer before it could possibly start obtaining new data packets. On the other hand, Hess, Kutzner, Spoel and Lindahl in (Hess, Kutzner, Van Der Spoel, & Lindahl, 2008) did not present any algorithm showing how a buffer size needs to be defined whenever. However, the solution is far too complex plus the estimation is just not accurate plenty of. Some other mechanisms made to reduce your delay released by reputable transmission plans for real-time programs are displayed in previous studied as stated earlier.

The particular UDP standard protocol is put on delay very sensitive applications as opposed to TCP because of its fast sign and light-weight (Fall & Stevens, 2011). To triumph over the unreliability associated with UDP, some completely new protocols depending on UDP were developed having schemes to scale back the data dropout proportion. UDP is a novel model of UDP. It ended up being proposed seeing that some researchers found that several “lost” packets received actually gotten to the in destination, but were discarded through the UDP standard protocol stack since they failed the actual checksum (Biagioni, Harper, Lee, & Milnes, 1994).

This led the researcher to conclude that using UDP can easily reduce how many discarded packets making the dropout proportion decrease (Lin & Dinda, 2005). Precisely why packet discards don't happen often for UDP will be that UDP permits partial checksums. Meanwhile, it also help simply verifies the actual error-sensitive percentage of a UDP datagram (El-Gendy, Bose, & Shin, 2003). This percentage is identified through the coverage field inside UDP header. If the actual error-sensitive section of the datagram doesn't fail the actual checksum, the main datagram is going to be delivered to the applications. In such cases, errors inside insensitive percentage of the datagram are ignored plus the packets which are delivered to the applications had been partially dangerous. This could help to report that the software may or might not fix the actual errors. As UDP is made for multimedia software, packets with unfixable mistakes only bring about a glitch and yes it not quite harmful (Wolfgang, 2003). As a result, UDP is able to improve the entire performance as well as quality of the much UDP dependent soft real-time software.

2.7 Congestion Control and Window Sizes

Congestion control and window sizes are usually two aspects that used in assessing protocol status in network related communication (Paxson, Allman, Chu, & Sargent, 2011). It relies on TCP in order to avoid packet dropping due to overspending information (Ghobadi, Yeganeh, & Ganjali, 2012). Window sizes utilized by the actual receiver to indicate how significantly data it might accept, and blockage control algorithms utilized by the actual sender to be able to perceive system congestion (Wischik, Raiciu, Greenhalgh, & Handley, 2011). Window sizes utilized to keep a sender through overwhelming a receiver with data further than its capacity to manage (Qazi & Znati, 2011). Overwhelming the peer with data inevitably causes the actual peer to be able to drop packets, which ends up with poor system efficiency (Dreibholz, Adhari, Becke, & Rathgeb, 2012).

However, each TCP message incorporates a window dimensions field inside header. The windowpane size is needed to specify the amount more information the peer is getting ready to receive (Barrera, Arce, & Bohacek, 2011). The sender will only send information beyond the actual window dimensions after receiving a new acknowledgement with the updated windowpane size. Data that may be written to the socket over the windowpane size could have its transmitting throttled (Carofiglio, Gallo, & Muscariello, 2012). As a result, window dimensions enable movement control for receivers in order to avoid overloading these people. A windowpane of dimensions zero indicates that this peer still cannot accept much more data, and the sender will minimize sending information until it truly is told or else (Papadimitriou, Welzl, Scharf, & Briscoe, 2011). Window dimensions updates are usually sent because dataless packets, and so are not known. In situation the windowpane update is often a lost package, the sender starts a continue to persist timer w hen it receives a window dimensions of absolutely nothing.

When the actual persist timer expires, TCP sends a little packet to the peer, which invokes an acknowledgement message that has the latest window dimensions (Alfredsson et al., 2013). While windowpane sizes remedy receiver blockage, TCP utilizes the blockage control mechanism allow senders to be able to perceive congestion inside network and throttle the traffic proactively. TCP implements a couple of algorithms: slow-moving start and congestion avoidance. These are very different algorithms with different targets, and perform together in order to avoid packet declines (Jung, Kim, Yeom, Kang, & Libman, 2011). They provide the rule that package drops on-line occur almost solely due to congestion 1 and so are best avoided for efficient networks. Data is delivered to the fellow, but the number of data will probably exceed none the receiver's windowpane, nor the actual sender's latest congestion windowpane. The worthiness of protocol signifies the sender's perception with the current congestion within the network links between the peers determined by recent effectiveness (Lar & Liao, 2013). Specifically, protocol usually stores the quantity of bytes which it believes could be reliably sent before looking forward to an acknowledgement to get returned. For that explanation with this section, we imagine protocol which can be reasoned to that it storing the quantity of packets rather than bytes.

2.8 Current Power Consumption Estimation Techniques

In order to provide a sufficient power estimation model for routers, the direct current (DC) is being duplicated to estimate the power consumption without interfering with the operating conditions of the processor under evaluation (Kawadia & Kumar, 2003). The current utilization of this method does not provide sufficient mean values, instead, it provide a waveform with the instantaneous current within a clock cycle (Palaniappan & Chellan, 2015; Ramachandran, Sheriff, Belding, & Almeroth, 2007).

Therefore, previous and current studies concerned about power estimation consumption configures current mirror with discreet transistors with possible inaccuracies due to the absence of matched characteristics and thermal stability. In addition, measurements of many clock cycles are difficult to be realized because of the large amount of data that must be recorded (Landsiedel et al., 2012b).

Based on this, various approaches were designed to look at the accuracy of the current mirror configuration for monitoring current variations with a different approach using modified capacitor technique (Yao, Huang, Sharma, Golubchik, & Neely, 2012; Youssef, Ibrahim, Abdelatif, Chen, & Vasilakos, 2014) which in a definite routing standard can achieve a sufficient estimation.

Meanwhile, Van Heddeghem et al. (2012) proposed reference power consumption values for Internet protocol/multiprotocol label switching, Ethernet, optical transport networking and wavelength division multiplexing equipment by providing an analytical power consumption model that can be used for large networks where simulation is computational. Authors used expensive and default calculation approaches based on optical bypass scenario. The simulation result showed that the analytical model to over 90% or higher and that optical bypass potentially can save up to 50% of power over a non-bypass scenario.

Furthermore, Kahng, Lin, and Nath (2012) proposed analyzing netlists of network on chip (NoC) routers by modeling of control and data paths followed by regression analysis to create highly accurate gate count, area and power models for NoCs. The proposed estimation models resulted average estimation errors of no more than 9.8% across micro-architecture and implementation parameters.

Furthermore, the non-ideal characteristics of the switches can produce in accuracies. In other approaches a digital multi-meter is being used in order to study the energy consumption of three commercial processors, based on an instruction energy model. Therefore, this study is conducted to provide a sufficient analytical model for power estimation consumption in routers.

2.9 Previous Works

Vishwanath, Zhao, Sivaraman, and Russell (2010a), reported on the efforts of previous circuit designers to enhance the power estimation in different settings based on the demand of commercial routing platforms. They addressed how the current power consumption estimation design do not necessary offer the coarse-grained, and the platforms suitable for monitoring and balancing power distribution in different schemes for saving energy. As such, the authors considered the use of NetFPGA platform, which is a popular routing platform for networking research, and make three new contributions. Initially, they obtained reduction-grained measurements from the power consumed due to the NetFPGA Gigabit router over an array of packet prices and package sizes. Then, they proposed a straightforward model that stops working power use of the NetFPGA router for the granularity of per-byte hard drive and per-packet control. Lastly, they pointed the ways of saving network energy depending based on the proposed model from consumption profile of router electric power.

P. Jamieson, W. Luk, S. J. Wilton, and G. A. Constantinides (2009), have evaluated the bi-directional and unidirectional FPGA routing architectures based on the amount of power consumption voltages associated with the power estimation framework for VPR. They aimed to enable FPGA vendors to locate the optimal FPGA configurations. In the initial stage, they constructed the basis for examining different types of routing architectures affect speed, area consumption, and power consumption. They were mainly concerned about determining the buffering affects during the routing sizing and its effect in delay and power and energy consumption of FPGAs with certain routing architectures. The evaluation result showed that uni-directional routing architecture, overall, the most electricity efficient decision is utilizing both inside the traditional FPGA domain as well as the mobile domain where time clock frequencies are generally fixed.

On the other hand, Wang, Hempstead, and Yang (2006), designed a realistic power consumption model of wireless communication subsystems typically to be utilized in simplifying the performance of sensor network node devices. Simple power consumption models regarding major factors were individually identified, and the effective transmission choice of a sensor node is modeled by the output power from the transmitting energy amplifier, sensitivity from the receiving lower noise amplifier, as well as RF atmosphere. Using this specific basic style, conditions regarding minimum sensor system power consumption were made for verbal exchanges of sensor data coming from a source device to some destination node. Power consumption model parameters were extracted for just two types connected with wireless sensor nodes that are widely utilized and retail available.

For typical equipment configurations as well as signal distribution circumstances, they found that sole hop routing can be occurred whenever the router always be more energy efficient in comparison with multi-hop routing. Further concern of verbal exchanges protocol cost to do business also demonstrates single routing could be more power efficient in comparison with multi-hop routing under realistic circumstances. This energy consumption model enables vendors to guide style choices at many different layers from the design space including, topology style, node position, energy effective routing plans, power management and the hardware style of future wireless sensor system devices.

Other researchers in (Chipara et al., 2006) resolve the inherent conflict between energy efficient communication by considering the possibility of enhancing the end-to-end communication delay by proposing and designing real-time power-aware routing (RPAR) protocol. The designed power estimation model for router was modeled to operate under specified communication delays at low energy cost by dynamically adapting transmission power and routing decisions. The model consists on different power indicator features in which an optimization of the voltage's flow is considered for resource-constrained wireless sensors. The simulation result showed that the proposed power consumption model for routers significantly enhanced the deadlines missed and energy consumption compared to existing real-time and energy-efficient routing protocols.

From these studies, it can be noticed that a lack of research associated with energy consumption for the devices is found. In addition, there is no comprehensive classification for the data that related to different types of switches and routers (Chabarek & Barford, 2011). A few papers have been discussing the issue of power consumption; some of them comprised the different types of routers and switches, and some comprised routers and switches from the same manufacturer. Some of these papers were useful by giving good information.

As reported by the European electrical energy, approximately 8% of power have been used by ICT equipment (Jääskeläinen, 2008). If there was no plan to decrease the energy consumption, then by 2020 the energy consumed by ICT equipment might grow more than 8% (Chabarek & Barford, 2011). One of the reasons of building and designing energy ware future systems is the ubiquity of ICT equipment and their propensity for power consumption by the increment in data rate.

Currently, it is considered as the best time for defining and explaining network devices such as switches, routers, servers etc. These devices are consuming large amounts of power. After phasing out these devices, it will be possible to replace them by an efficient part (Anoh & Alani, 2011).

It is clearly seen that Cisco, Huawei and Juniper routers have and energy consumption scales similar for their total aggregate productivity (throughput). Routers have witnessed and increment in their energy and this because of their increasing productivity, while the energy consumption trends are consistent among different types of vendors of routers.

For routers power consumption, Chabarek et al. (2008) developed a generic power model. It was the first study in this side. At the beginning of their experiment, they aimed to measure the power consumption of two idle routers by putting into consideration that these routers have different line card combinations. The routers were Cisco 7507 and Cisco GSR 12008, they consumed that there was consumption of power for each router more than half of the maximum observed power for any configurations. They found that it is better to minimize the chassis number that are using the router power and minimize line card quantity per chassis. They set up a testbed of 20 workstations for traffic generation at their 2^{nd} set of experiment (Chabarek et al., 2008).

In order to get a significant energy saving in operational network, it is important to design a generic power model. Power conservation for computer networks has been addressed in a different context, load balancing and power provisioning in data centers (Chase, Anderson, Thakar, Vahdat, & Doyle, 2001; Fan, Weber, & Barroso, 2007), network switches (Arlitt & Jin, 2000; Gunaratne, Christensen, & Nordman, 2005; Gupta, Grover, & Singh, 2004; Gupta & Singh, 2003; Nedevschi, Popa, Iannaccone, Ratnasamy, & Wetherall, 2008), wireless networks (Agarwal et al., 2007; Committee, 1997; Jardosh, Iannaccone, Papagiannaki, & Vinnakota, 2007; Shih, Bahl, & Sinclair, 2002) and mobile phones (Flinn & Satyanarayanan, 1999; Yuan & Nahrstedt, 2003).

Wireless networks traditionally focus on power conservation. Wake-on-wireless (Shih et al., 2002) and Cell2Notify (Agarwal et al., 2007) propose on-demand powering up of the wireless interface using intelligent signaling. This ensures that the interface need not be on during idle periods thereby saving power. The IEEE 802.11b specification (Committee, 1997) includes schemes by which access points buffer packets so clients can sleep for short intervals. Wake-on-LAN is an Ethernet networking technology that allows a computer to be woken up by an incoming network packet. This is useful to allow computers to be put to sleep during idle periods, leaving the Wake-on-LAN enabled network interface card switched on.

The computer can be woken up remotely using a special "magic" packet. The Wake-on-Packet facility that we assume in our algorithms and advocate for future switch designs is similar to Wake-on-LAN. Using this facility, switch ports that are powered down are automatically woken up on any incoming packet. Other recently reported research have assumed similar support (Gupta et al., 2004; Nedevschi et al., 2008). Gupta and Singh (2003), was an early work that identified the Internet's high power consumption and explored performance effects due to network-wide coordinated and uncoordinated sleeping. They followed their work in (Gupta et al., 2004) by devising low-power modes for switches in a campus LAN environment.

While our Time Window Prediction scheme is related to that of (Gupta et al., 2004), we take better advantage of extended idle periods as our scheme is based on observations.

In a time-window while (Gupta et al., 2004) requires the port to be on throughout the idle period. This advantage is significant when the traffic patterns are bursty with long idle periods. Also, we introduce latency bounds and investigate the effect on latency and packet loss. Gunaratne et al. (2005) and Nedevschi et al. (2008) look at intelligent scaling of switch link speeds depending on network flow. For example, a link need not be active at 1 Gbps if 100 Mbps is sufficient for the traffic.

An important practical problem is that the speeds on the switch are discreet (10 Gbps, 1 Gbps, 100 Mbps and 10 Mbps) and hence taking advantage of this automatic scaling would require vast differences in the traffic flows. This problem is acknowledged in (Gunaratne et al., 2005) where they test their algorithm with non-existing link speeds of 20 Mbps, 30 Mbps and 40 Mbps. (Nedevschi et al., 2008) also admits to this where the testing on the exponential distribution of speeds gives relationfly worse results.

Automatic scaling of give speeds also incurs the overhead of auto-negotiation of link speeds between the endpoints (Nedevschi et al., 2008).

2.10 Clock Frequency

Reducing the clock frequency is beneficial for power consumption reduction and has the same effect as that of reducing the capacitance of the circuit. Eliminating the unwanted logic switching will help to reduce the clock frequency. The other factors that can help to reduce the switching frequency are: changing the number representation and coding forms, finding an alternate logic design for the same circuit, etc. Reducing the switching frequency will improve the system reliability (Yeap, 2012).

The main factors on which the processor power dissipation directly depends on are the load capacitance, supply voltage and clock frequency. For low power consumption, the processor voltage and frequency has to be reduced without violating any other specifications. The key technique for power consumption reduction of an embedded processor is Dynamic Voltage Frequency Scaling (DVFS), in which the processor is operated at different operating points which is a duple of supply voltage, clock frequency (Pillai & Isha, 2013).

the main variables affecting dynamic power are capacitance charging, the supply voltage, and the clock frequency, While the power reduction declines for an equivalent circuit from process node to process node, the FPGA capacity doubles and the maximum clock frequency increases (Consumption, 2012).

operating a device at a lower frequency can enable dramatic reductions in energy consumption for two reasons. First, simply operating more slowly offers some fairly substantial savings. For example, Ethernet links dissipate between 2-4W when operating between 100Mbps-1Gbps compared to 10-20W between 10Gbps. Second, operating at a lower frequency also allows the use of dynamic voltage scaling (DVS) that reduces the operating voltage. This allows power to scale cubically, and hence energy consumption quadratically, with operating frequency. the shortest distance service curve would achieve the highest possible energy savings (Nedevschi et al., 2008).

Dynamic voltage and frequency scaling (DVFS) is a commonly-used power-management technique where the clock frequency of a processor is decreased to allow a corresponding reduction in the supply voltage. DVFS is able to reduce the power consumption of a CMOS integrated circuit, such as a modern computer processor, by reducing the frequency. The voltage required for stable operation is determined by the frequency at which the circuit is clocked, and can be reduced if the frequency is also reduced. Energy can only be saved if the power consumption is reduced enough to cover the extra time it takes to run the workload at the lower frequency (Le Sueur & Heiser, 2010).

Larger packets in general require higher transmission/reception energies than smaller packets. while the storage energy increases linearly with packet size, since larger packets occupy more memory space. Third, the packet processing energy, which is the energy consumed for header processing, ARP lookups, etc., is independent of the packet size, since these operations have to be performed on each and every packet, regardless of its size. Finally, we observe that there is a constant (base line) power consumed by the router when it is idle, and not subjected to any traffic load (Vishwanath, Zhao, Sivaraman, & Russell, 2010b).

Zhang, Yi, Liu, and Zhang (2010), suggested to consider routers in the network context and create more power saving opportunities by adjusting the amount of traffic going through routers, but they did not propose specific solutions, while the claimed that today's networks are designed and operated to carry the most traffic in the most reliable way without considerations of energy efficiency.

P. Jamieson, W. Luk, S. J. Wilton, and G. Constantinides (2009), investigated the impact of routing buffer size on the two types of routing architectures. Their main goal was to find the best energy consuming architecture depending on the required clock frequency, meanwhile they found that dynamic power has linear dependency on the clock frequency and a quadratic dependency on the supply voltage.

2.11 Summary

This chapter described the main component of this study in terms of power estimation issues for routers in different network flows. TCP and UDP protocols are introduced in contrast with current trends related to network power estimation in communication related settings. The types and vendors of routers were also addressed in which it was used as a guide to simulate the power estimation purposes. The previous studies were also introduced in order to show the gap associated with the current lack of power estimation consumption technique for routers and protocols in different trrafic settings.

CHAPTER THREE

RESEARCH METHODOLOGY

In this chapter, the approach in undertaking the research work has been outlined. Model configuration and simulation setups and the basic components have described. Also the parameters that characterize the estimation power consumption in router are being defined, input and output parameters that involves throughout this thesis.

3.1 Simulation Design

Due to fact that the router system consists of components from different vendors, it is very complicated to simulate the whole system, so a sample simulation has been provided for Xilinx Virtex-5.

Virtex-5 acts as the data processing unit responsible for understanding Ethernet messages headers, while it forwards the message towards the right port according to the results of header processing.

In order to simulate the power consumption, the following execution steps were considered by the researcher:

1. Determine the processing requirements: due to the fact that the Ethernet header is up to 480 bits, the processing shift register must be ready to process the header in its worst case or in its maximum size, so the shift register was implemented to be 480 bits.
2. Draw block diagram that show the flow of the data from its raw input form to its final output form.
3. Break down each block into its Gate level components, for example the Virtex-5 is equipped with 480 bit+ shift register. As such, it is meaningless to redesign a shift register from scratch.
4. Set the simulation and compare the results for different wavelengths, traffic types and frequencies. The results graphs must be processed in MS Excel in order to compare between them..

3.1.1 **Wavelength**

In order to set up the wavelength performance on the proposed power consumption estimation model, a Tunable Light source MLS-2100 has been simulated in order to generate the required test signal for the characterization of multiple routers. This device usually used to control and supplies power to external cavity tunable source necessary for generating the single-photon router signal. It also use interference filter in the external cavity for wavelength control and selectivity.

The oscillation wavelength can be widely tuned by controlling the loss against the components in selecting wavelength inside of external cavity module. The output wavelength tuning range was configured from 1530nm to 1630 as shown in Table 3.1.

Table 3.1: Single-photon router characteristics

Parameter	**Unit**	**Min.**	**Spec.**	**Max**
Wavelength settings				
Tuning Range	nm	1530	-	1610
Minimum Tuning	nm	80	-	-
Resolution	nm	-	-	0.024
Accuracy	nm	-	-	0.1
Repeatability	nm	-	-	0.01
Stability	nm	-	-	0.01
Fine tuning range	GHz	200	-	-
Power settings				
Output power	dBm	-30	-	13
Accuracy	%	-	-	5
Repeatability	dB	-	-	0.01
Flatness	dB	-	-	0.02
Built in attenuator	dB	0	-	20
The tested single-photon router conditions				
Operating temp	℃	20	-	30
Operating humidity	%	-	-	80
Storage temperature range	℃	10	-	80

3.1.2 **Router Power Configuration**

In addition to providing wide wavelengths covers, the simulated Tunable Light Source (TLS) MLS-2100 was used to feed the router power in order to estimate the power consumption performance in different sessions.

3.2 Performance Parameters

Since most previous power estimation techniques relied on statistical traffic models, or analytical models, the researcher configured the simulation environment to perform on gate levels. However, it is time consuming and not practical for external routers. The researcher was also interested in determining the model outputs in a definite power conditions. The researcher identified the performance parameters as outputs of the system. The number of output stocks and signal stability are represented the major parameters as described below:

3.2.1 **Number of Output Stocks**

The number of output stocks was considered in order to determine the peak differences in power consumption estimation in which it cannot transmit all wavelengths within the band, and because of that, the number of channels is finite. Therefore, the narrowest spacing between channels can provide a larger number of channels that can be transmitted.

3.2.2 **Signal Stability**

The stability of output power is studied experimentally. The power estimation stability was estimated based on measuring the peak power of the output stokes at different times, with respect to fixed 480 bits shift register and power source.

3.3 Setting Virtex-5

Virtex-5 data sheet and testing configurations can be found in 3, 2, 1, and 2L speed grades in which 3 having the highest performance. The router devices with 2L usually run at change core voltage (VCCINT) = 1.0V and are screened for lower maximum static power.

In addition, the device set at 2G speed grade supports 12.5 Gb/s GTX or 13.1 Gb/s GTH transceivers. Figure 3.2 shows the write and read commands performed on proposed power consumption estimation model.

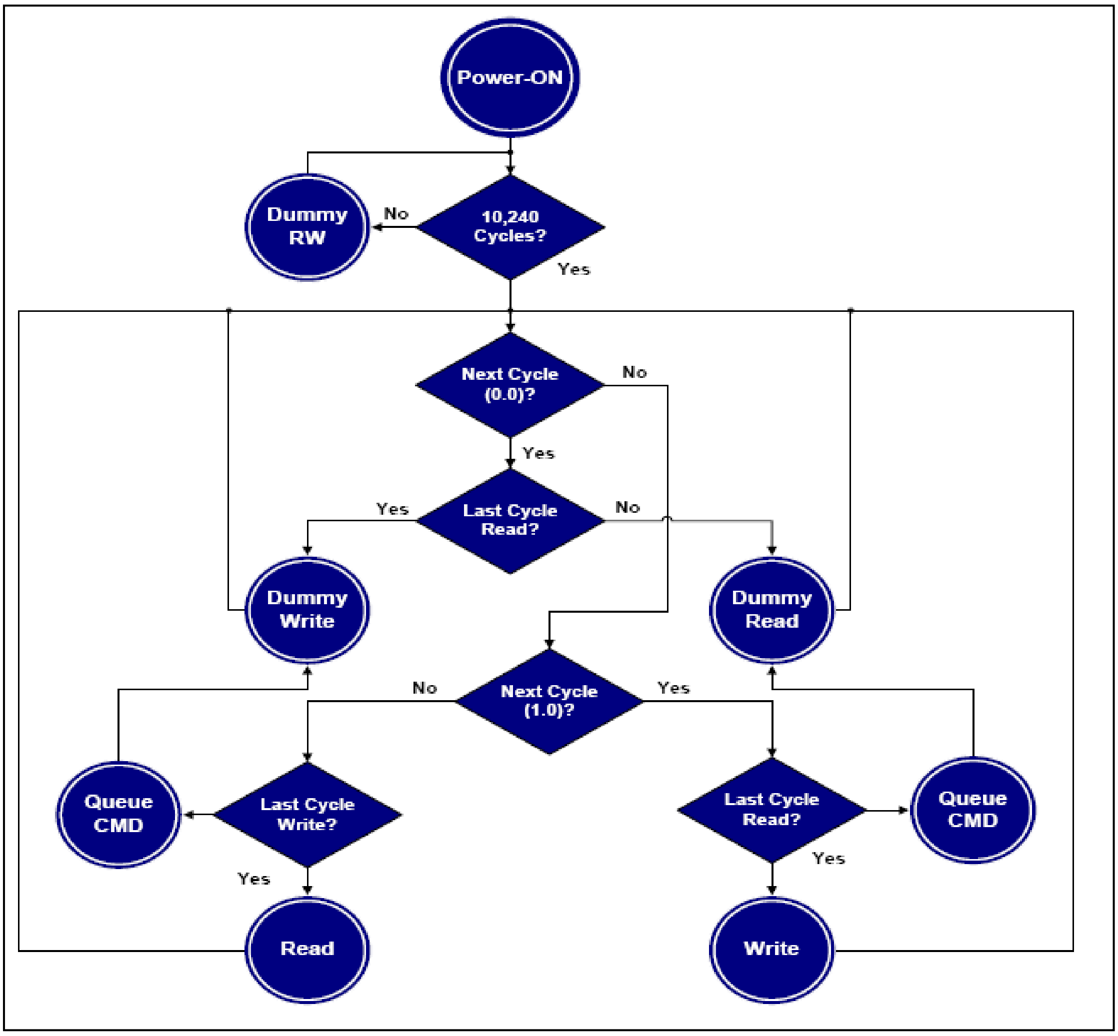

Figure 3.1 Write and read commands performed on proposed power consumption estimation model

The Virtex-5 characteristics were obtained from the datasheet available at Xilinx website "www.xilinx.com".

3.4 TCP and UDP Settings

Table 3.2 shows the embedded settings for both TCP and UDP protocols, this include setting the port with the number of sequences corresponded to assemble power level in router. The protocols were also set to accept data rate of 515 with activation enabled. However, UDP data rate was set to 1048 with activation enabled for VHLD. This helped to provide a flexible communication for estimating power consumption.

Table 3.2: TCP and UDP settings

	Usage	Port#
TCP	Command	443
		3268
		389
	Data	8080
		31865
		515
	Audio	1688
	activation	TCP 8000
UDP	Device Discovery	1047
		1048
		1049

Figure 3.3 shows the proposed topology for evaluation, the Xilinx was used to deliver a generation of FPGAs at 1480, 1570, and 1750, although this tools provide 28nm and 20nm only, the researcher had to integrate external library for the aim of handling longer wave with multiple packet transmitted in sequential order. The

figure shows that the projected signal from the pc will be set to three power levels in which distributer director was amplified in the simulation based on the proposed multiplexer design to the router. Then the received signal from router is processed and used for comparison related aspects. TCP and UDP were extracted and compared in the next chapter.

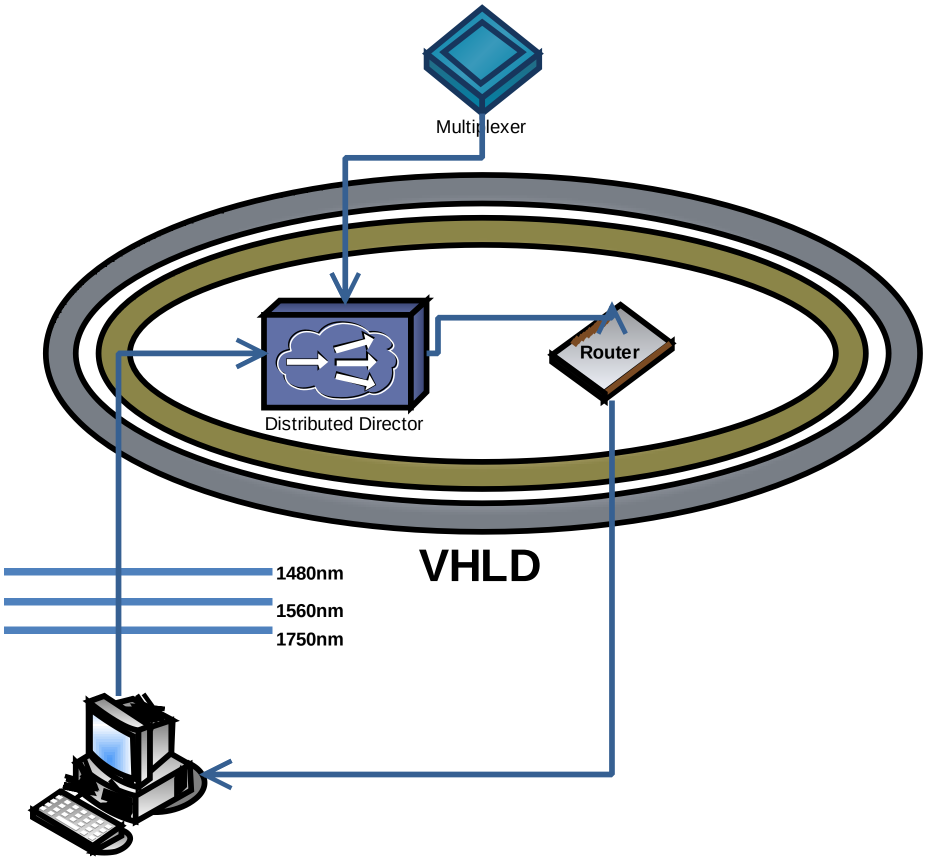

Figure 3.2: Network topology

3.5 Summary

This chapter summarized the design procedure of the proposed power consumption estimation model along with the router manufacture datasheet specifications. It also explained the steps involved in simulating the proposed model based on the power source projected over TCP and UDP protocols based on the frequency rate. The expected performance measures and its stability are introduced in the next chapter.

CHAPTER FOUR

RESULTS AND FINDINGS

4.1 Introduction

This chapter introduced the process of simulating the proposed power consumption estimation model. It starts with the formulas for power estimation designed by the researcher based on the review of power estimation approaches in the literature. A comparison of power estimation between TCP and UDP is provided based on the regulation of wavelength dimensionality in Xilinx tool, this environment was used to allow programming VHDL for the aim of incorporating the proposed power estimation into the working scenario of these protocols. The sequences for changing power level associated with the controller in each protocol was set to 2.3gh in order to provide a harmonic distribution of power to the router’s gates.

4.2 Simulation Result

Since the main customizable simulation is the Xilinx Virtex-5, this was the focus of simulation, so a header processing circuit had to be built from scratch to suit IP version 4 processing of the header and TCP, UDP for different settings.

The processing system had to put into consideration the number of ports which doesn't make linear proportion to the power or processing, where the power and processing are rather exponentially proportional to number of ports since this increases the possible combination of sending and receiving in case the LAN traffic was higher than the WAN traffic.

In order to validate the claimed results, the researcher simulated the proposed power estimation over two protocols (TCP and UDP) to infer the router performance based on the socket associated with these protocols. This was to provide additional insights to compare the router performance in different power levels, three power levels are used in order to do so (1480nm, 1560nm, and 1750nm). The following sections address the process and comparison result is also provided.

4.3 Estimated Power Port Results

During simulation, many bugs were found by comparing the datasheet estimated power and the simulated output power.

To obtain a simple and repetitive simulation, a single input port and single output port were used, while the average power was obtained from multiplying a single I/P single O/P power by 8 (Which is the typical consumption during WAN communications). In addition, the researcher obtained the maximum power from multiplying the single I/P single O/P power by 15 (Which is the typical consumption during LAN communications). This was also applied for UDP and TCP in which the design was mainly associated with port with internal data processing. The working scenario for incorporating the proposed power estimation into the design of UDP and TCP using VHDL as a programming language.

After completing this comprehensive training, the researcher set the following setting:

1. Implement the VHDL portion of coding for synthesis.
2. Identify the differences between behavioral and structural coding styles.
3. Distinguish coding for synthesis versus coding for simulation.
4. Use scalar and composite data types to represent information.
5. Use concurrent and sequential control structure to regulate information flow.
6. Implement common VHDL constructs (Finite State Machines [FSMs], RAM/ROM data structures).
7. Simulate a basic VHDL design.
8. Write a VHDL test bench and identify simulation.
9. Identify and implement coding best practices.
10. Optimize VHDL code to target specific silicon resources within the Xilin x FPGA.
11. Create and manage designs within the Vivado Design Suite environmen.

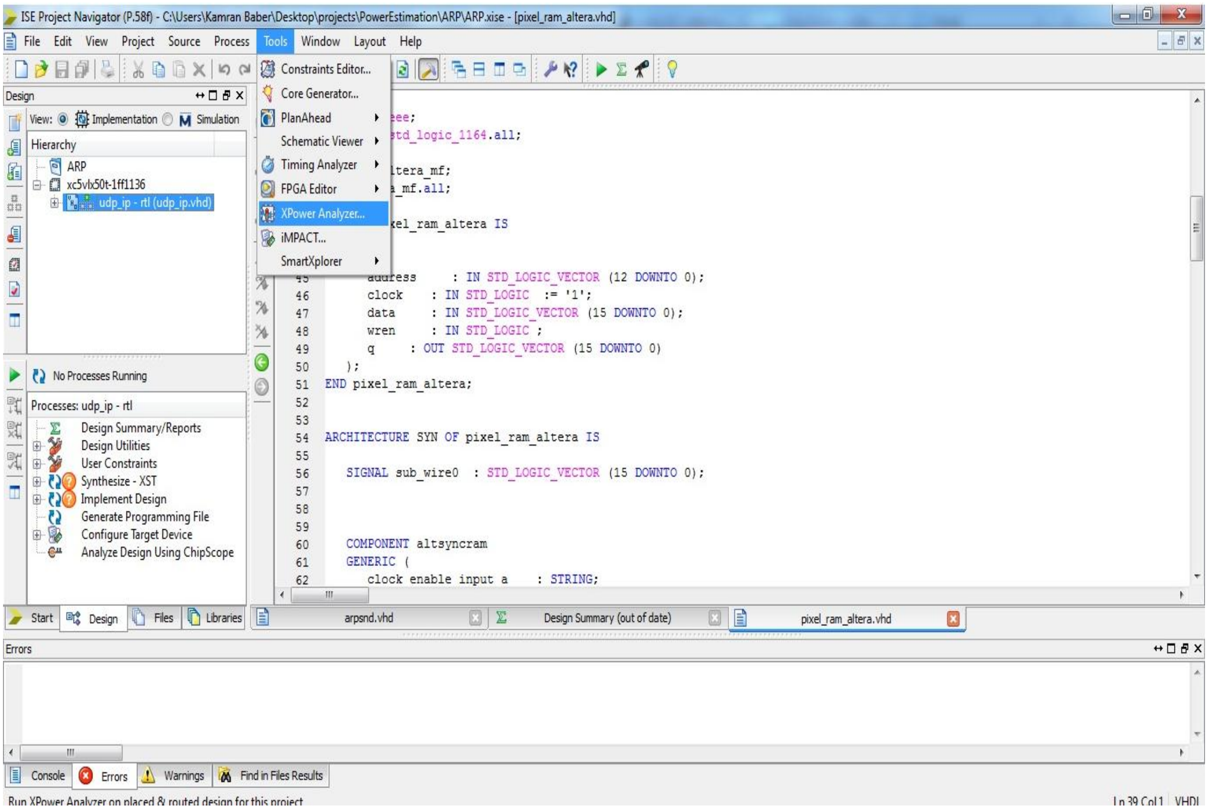

Figure 4.1: Vivado Design Suite Interface

4.4 Wavelengths Results

After mediating the power estimation parameters in to the tool, the researcher had to set the wavelength to different levels by embedding the power level into the operator of router. After that, the researcher executes the power estimation over TCP and UDP and result obtained were used for comparison of performance. Based on Figure 4.2, the researcher found that 1480 nm pump power over TCP and UDP protocols essentially better in TCP than UDP, this can be reasoned to that power distribution is mostly corresponded to protocol role in balancing number of packets with network demands, having this in mind, TCP was found to do well in which transmitted packets with network power demands of 1480nm achieve a smooth result.

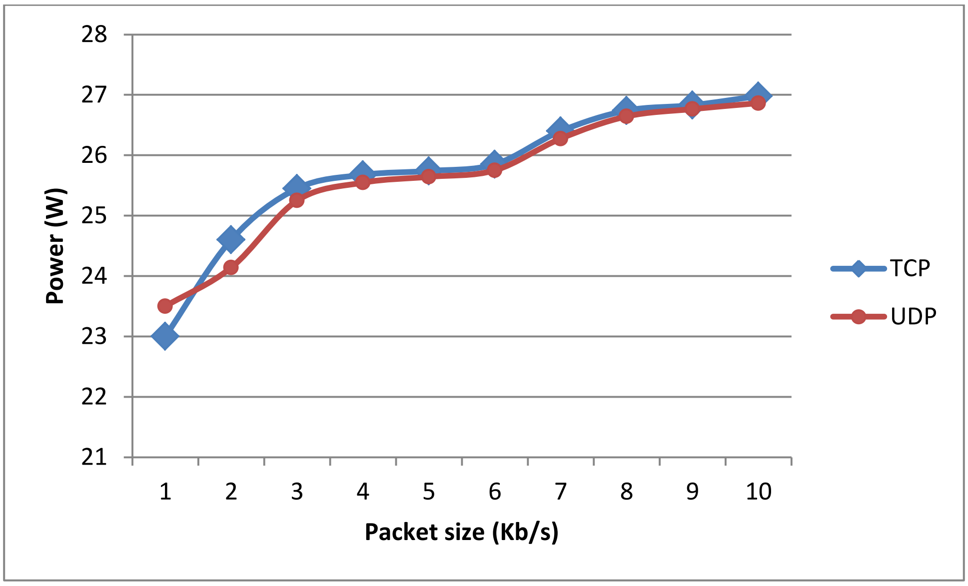

Figure 4.2: TCP and UDP router power estimation stability based on stokes power against 1480 nm power source

On the other hand, Figure 4.3 presents the differences in power consumption performance based on the 1560 nm router power source over TCP and UDP. The configuration of wavelength rate in this study was identified based on the recommendation of previous studies related to offering suitable wavelength for power estimation purposes. The result of the power estimation in TCP was found to be better that UDP as the performance peak is improved once increment of the packet size in which led to consistent router estimation performance. The result showed that the range of power wavelengths in router is responsible of achieving higher peak at 1598.6 nm. Meanwhile, the researcher found that the proposed power consumption estimation offered stable power estimation based on the generated signal from the power stokes obtained from peak gain wavelength.

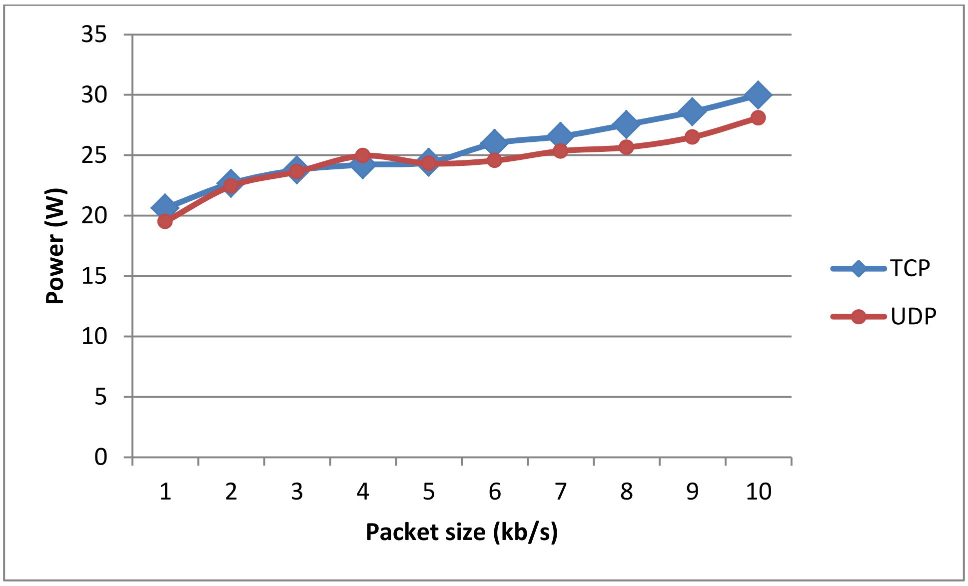

Figure 4.3: TCP and UDP router power estimation stability based on stokes power against 1560 nm power source

Meanwhile, the power estimation of router in 1750nm was also tested. The result presented in Figure 4.4 showed that estimated power stokes was found to be stable in both protocols with the increase of packet size in 1750 nm. Having this in mind, the power consumption of a circuit can be reduced based on monitoring the peak gain of power source projected to the stoke signal. This result provides necessary implications for future work to consider the length of wavelength in testing the stability of power estimation mechanisms. This also includes the testing of protocol in LAN and WAN settings which found to be stable and prove the proposed model efficacy.

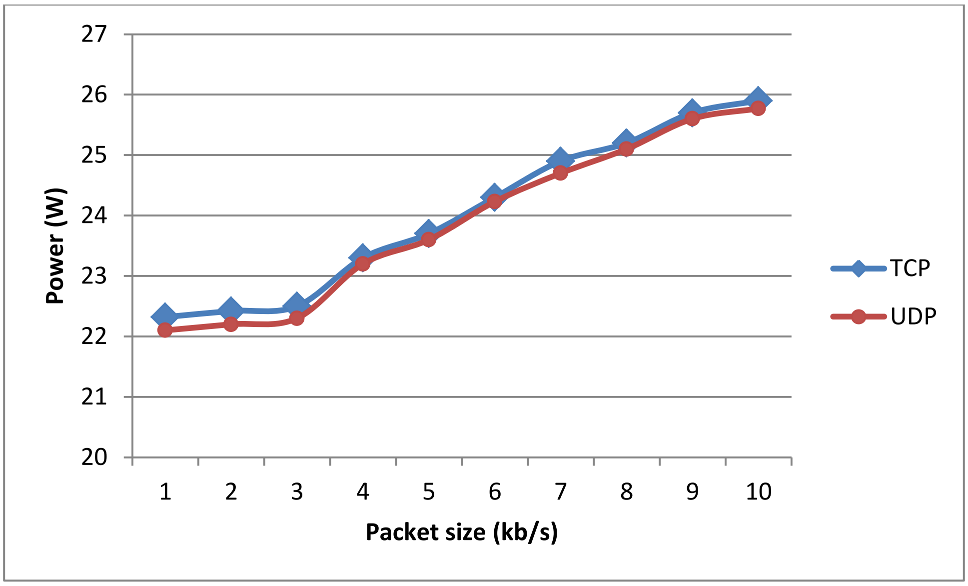

Figure 4.4: TCP and UDP router power estimation stability based on stokes power against 1750 nm power source

4.5 CBR and HTTP Results

In order to get a clear view about the power usage of TCP and UDP protocols, we examined the case of transition. For TCP, Hyper Text Transfer Protocol (HTTP) service has been simulated while for UDP, Constant Bit Rate (CBR) service has been simulated. The results from these simulations proved that CBR has a stable usage of power due it's working type. While HTTP has a frequent usage. Figure 4.5 shows the resluts obtained form this simulation.

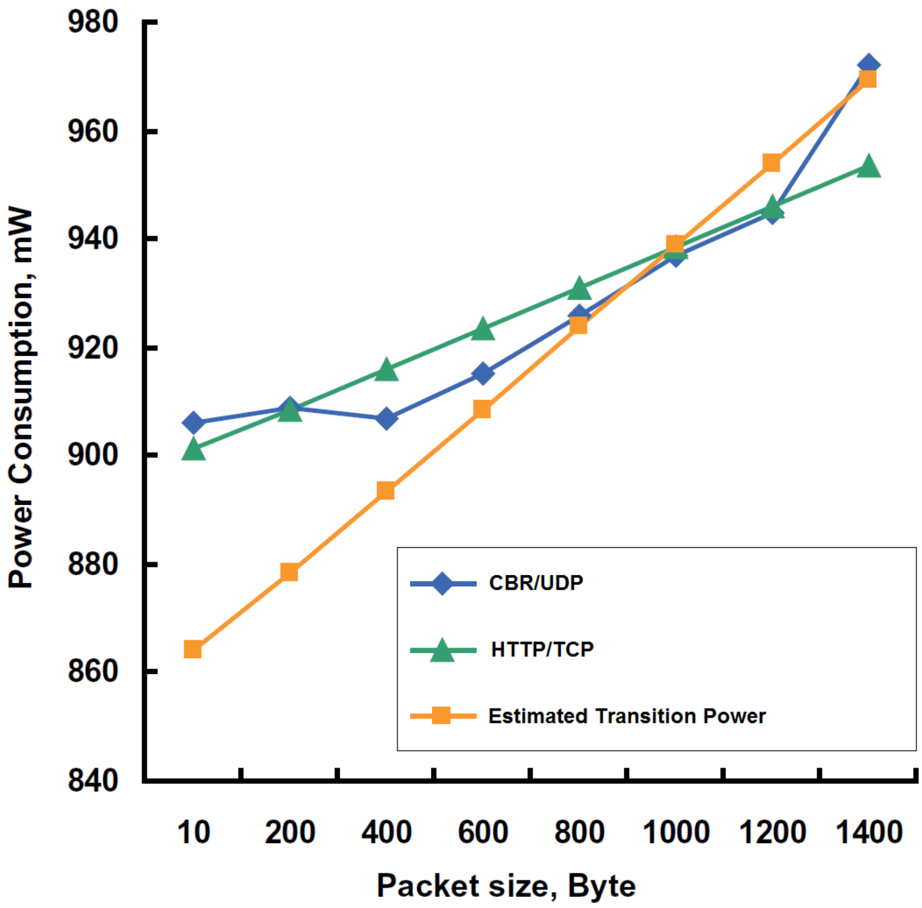

Figure 4.5: CBR and HTTP Power Usage for 10ms Transition Time

4.6 Clock Frequency Results

Many studies argued the clock frequency and its' effect on the level of power consumption, but there is a lack to the studies which discuss the clock frequency on the transport protocols. Hence, it was necessary for the researcher to examine different frequencies and its' effectiveness on power consumption for the protocols.

The figure 4.6 shows a huge different for the two protocols power consumption based on different frequencies. It is clearly seen that TCP consumes a higher power with higher frequencies, while UDP is alomost stable in most frequencies with a low power consumption.

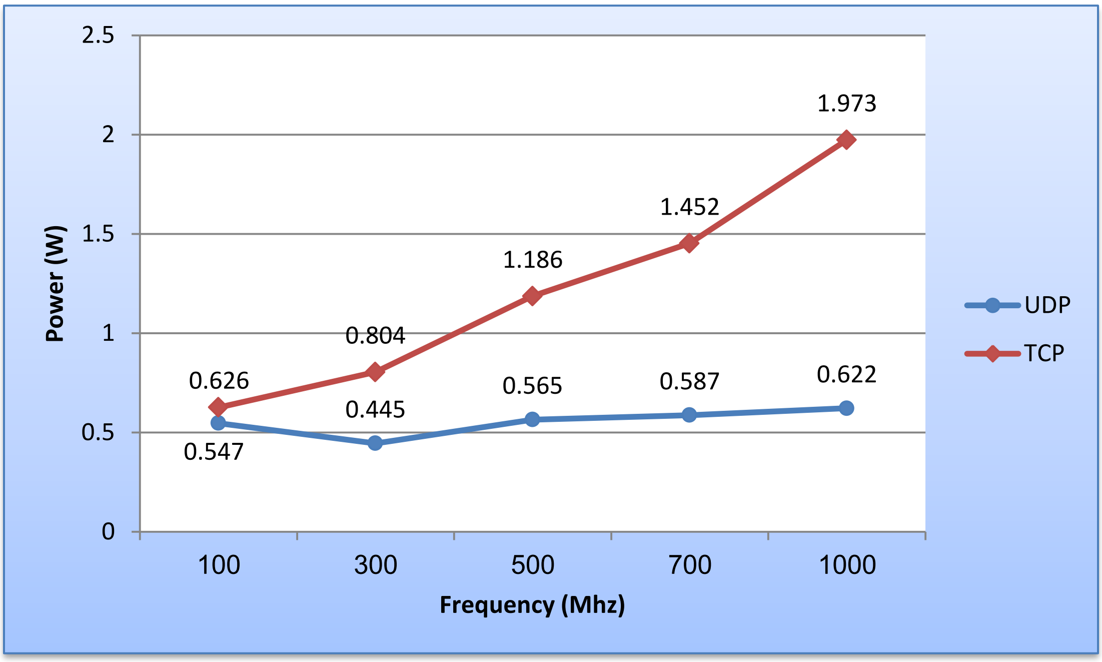

Figure 4.6: TCP VS UDP Power Consumption based on Different Frequencies

4.7 Summary

This chapter examined the formulas designed by the researcher to deliver the proposed power consumption estimation model based on peak gain of external power source wavelength in router circuit. The proposed model was tested based on the stability and output stocks performed in different power range. The result showed that the proposed model has the potential in estimating the power consumption in routers under different power change circumstances.

CHAPTER FIVE

DISCUSSION AND CONCLUSION

5.1 Introduction

In order to provide a sufficient power estimation model for routers and its' protoclos, the direct current (DC) is being duplicated to estimate the power consumption without interfering with the operating conditions of the processor under evaluation (Kawadia & Kumar, 2003). The current utilization of this method does not provide sufficient mean values, instead, it provide a waveform with the instantaneous current within a clock cycle (Palaniappan & Chellan, 2015; Ramachandran et al., 2007).

This study therefore looked at the aspects related to calculating the power consumption estimation of router and its' protocols in different settings by obtaining static power of router followed with simulating power consumption of a selected router protocols to ensure that the average power is constant regardless the setting. In addition, the researcher compared the simulation results of the estimated power consumption in TCP and UDP protocols whereas the wavelength power was set to 1480nm, 1560nm, and 1750nm. The result showed that the model of power consumption estimation for routers has the potential in providing consistent measures under different power change circumstances.

5.2 Discussion

Previous and current studies concerned about power estimation consumption configures current mirror with discreet transistors with possible inaccuracies due to the absence of matched characteristics and thermal stability. In addition, measurements of many clock cycles are difficult to be realized because of the large amount of data that must be recorded (Landsiedel et al., 2012b).

Based on this, various approaches were designed to look at the accuracy of the current mirror configuration for monitoring current variations with a different approach using modified capacitor technique (Yao et al., 2012; Youssef et al., 2014) which in a definite routing standard can achieve a sufficient estimation.

Meanwhile, authors in (Van Heddeghem et al., 2012) proposed reference power consumption values for Internet protocol/multiprotocol label switching, Ethernet, optical transport networking and wavelength division multiplexing equipment by providing an analytical power consumption model that can be used for large networks where simulation is computational. Authors used expensive and default calculation approaches based on optical bypass scenario. The simulation result showed that the analytical model to over 90% or higher and that optical bypass potentially can save up to 50% of power over a non-bypass scenario. The result provided in this study shows a better potential in which the power estimation accuracy in different network traffic sessions was within the manufactory's data sheet provided. This in turn led the researcher to conclude that constructing power consumption estimation model can deal with several factors associated with the configuration of network in different settings.

Furthermore, authors in (Kahng et al., 2012) proposed analyzing net lists of NoC routers by modeling of control and data paths followed by regression analysis to create highly accurate gate count, area and power models for NoCs. The proposed estimation models resulted average estimation errors of no more than 9.8% across micro-architecture and implementation parameters. Having such model tested in such settings may not necessarily fits the need of other bandwidth settings. Therefore, the researcher believe that result obtained from this study provide more insightful outcome in which network traffic in different session was tested with consideration of wavelength transmitted within the router's circuit.

Furthermore, the non-ideal characteristics of the switches can produce in accuracies. In other approaches a digital multi-meter is being used in order to study the energy consumption of three commercial processors, based on an instruction energy model. Therefore, the result obtained in this study is promising to provide a sufficient analytical model for power estimation consumption in routers.

5.3 Limitation

This study was limited to number of aspects related to the protocol optimization in which it poses a challenge to provide a real estimation as compared to the simulation. The simulation of the proposed model was limited on heavy traffic scenario in which power stability was set to a definite sequence gain of 1480 nm, 1560nm, and 1750nm. Meanwhile,different frequencies have been set to the simulation in order to find out its' effectiveness on TCP and UDP. The testing of the model was also limited to the peal of distributed routing network in which the peak gain was measured based on the packet size transmited over TCP and UDP. Other protocols can also be examined in order to provide more evidence of the proposed power estimation efficiency.

5.4 Future Works

Since the proposed model of power consumption estimation for routers has been tested and solved the present research questions. There are still some improvements that can be attempted for future work. This include the utilization of Raman amplifier can be used as a remotely controller of the power distribution with high transition data rate of 25Gb/s or 40Gb/s projected within a high and ideal network traffic flows. Meanwhile, additional multiplexer can be used to facilitate the transmission of heavy traffic by boosting the launched signal power. In addition, the cost estimation for designing the circuit could take in account the maximum distance high data rate of power.

5.5 Conclusion

This study has successfully build and texted power consumption estimation model for routers in different traffic settings. The design was tested on a simulated protocols in which the result obtained from sure measures revealed a potential in meeting the measures of router’s data sheet. The result of the power estimation in different wavelengths revealed that total stokes power increases router estimation performance consistently with power source and wavelength peak gain. This study also found that the estimated power stokes was high when the 1480nm, 1580nm, and 1750nm power source increase. This was noticeable for TCP protocol which showed better performance in power estimation compared to UDP. The limitation of resources can be overcome in the future work by considering more network settings and circuit design components.

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