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Energy Efficient Packet Processing Engine

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Abstract: Energy efficiency in all the aspects of human life has become a major concern, due to significant environment impact as well as it economic importance. Information and Communication Technology (ICT) estimated 2-10% of the global consumption but is also expected to enable global energy efficiency through new technologies tightly dependent on networks. Specially, a network model based on G-network quening theory is built, which can incorporate all the important parameters of power consumption together with traditional performance metric and routing control capability. Our goal is to control both power configuration of pipeline and way to distribute traffic flow among them. Optimization policy having best tradeoff between power consumption and packet latency times. The achieved results demonstrate how the proposed model can effectively represent energy and network-aware performance indexes.

Keywords: Adaptive rate, green networking, low power idle, network traffic.

1. INTRODUCTION

The power consumption of Information and Telecommunication Technology (ICT) has become a major issue in the last few years. According to some studies, ICT covers 2-4% of the global energy consumption, while this rises up to 10% when considering only developed countries like the United Kingdom. The energy consumption of the Information and Communication Technologies (ICT) sector has followed an increasing trend in the last several years and it is estimated 2020 to keep the global temperature increases [1].

The increasing trend in the energy consumption of the ICT sector has also been confirmed in recent reports published by large Telecom operators (Telcos) and Internet Service Providers (ISPs) worldwide. In 2006, the overall energy consumption of Telecom Italia had already reached more than 2 TWh (approximately 1% of the total Italian energy demand), which was an increase of 7.95% over 2005 [2-4] in 2009, this consumption increased to 2.14 TWh. Another representative example is from British Telecom, whose overall power consumption for its network and estate during the 2010 financial year was 3.12 TWh [5, 6]. The Deutsche Telecom group reported an overall energy consumption of 7.91 TWh during 2009, compared with 3 TWh in 2007 [7], and this group attributes the steep increase to technology developments, increasing transmission volumes and network expansion. The power consumption of Verizon in 2010 was 10.24 TWh, up from 8.9 TWh (approximately 0.26% of USA's energy requirements) in 2006. AT&T accounted for 11.14 TWh in 2010 and declared a consumption of 654 kWh per terabyte of data carried on its network in 2008. The requirements of France Telecom were approximately 4.38 TWh in 2009 [8], while it is committed to a 15% reduction in its global energy consumption by 2020 relative to the 2006 level. In 2010, the Telefonica group consumed 6.37 TWh, compared with their 2006 figure of 1.42 TWh, which amounts to 0.6% of Spain's total energy consumption [9]. The NTT group reported that the amount of electrical power needed for telecommunications in Japan was 4.2 TWh in fiscal year 2004 [10] and that their direct energy consumption amounted to 2.75 TWh in 2009. Finally, China Mobile's energy requirements since 2009 have exceeded 10 TWh, an annual increase of more than 1 TWh. In parallel with the increase in energy consumption, an even more aggressive trend is observed in Internet traffic, as well as in the number of devices connected to the Internet.

Worldwide, the growth rate of Internet users is approximately 20% per year, while in developing countries; this growth rate is close to 40–50% [11]. According to the Cisco Visual Networking Index [12], global IP traffic has increased eightfold over the past 5 years and it will increase fourfold over the next 5 years. Overall, IP traffic is estimated to grow at a compound annual growth rate of 32% from 2010 to 2015, with busy-hour traffic growing more rapidly than the average rate. It is important to note that in 2010, global Internet video traffic surpassed global peer-to-peer (P2P) volume, and by 2012 Internet video is predicted to account for over 50% of consumer Internet traffic [12]. Considering these facts, as well as predictions for the near future, a reduction in the total energy consumption and, consequently, in the carbon footprint of the ICT sector appears to be quite desirable. According to GeSI [11], if applied to improve the energy efficiency in other sectors, ICT is seen to have the potential to eliminate approximately 15% of the global carbon footprint. A fortiori, ICT should apply the same energy efficiency awareness to its known operations; this is indeed happening, due also to the economic constraints that stem from the need to counterbalance the ever-increasing cost of energy with the desired level of performance of network and computing devices. However, to achieve this kind of reduction in the energy consumption of next generation networks and devices, new paradigms have to be introduced in both design and daily operation phases. As a relevant example for this paper, the energy efficiency of network devices needs to be significantly improved and, in parallel, advanced mechanisms have to be developed for optimal network operations relative to the total energy consumption. Thus, there is a need to introduce energy-efficient techniques both at the device level and at the network level. Such techniques need to be developed and applied because the design of the Internet and even recent evolutions

do not address energy consumption issues [12]. Today, over provisioning is adopted in dimensioning both the number and the capacity of network devices and links. The degree of over provisioning depends on the maximum load that the network has to carry during its peak hours, which is directly connected with the peak energy consumption of the network, as well as with the redundancy degree of the network. This degree of over provisioning is selected for increased resiliency and fault-tolerance of the current networks. In addition to the redundancy level of devices and links in the network that increase the total energy consumption, any drop in traffic is not followed by a corresponding drop in the amount of energy consumed by the network, which is largely due to the lack of energy proportionality in the current generation of network devices, which consume close to their peak energy independently of their actual traffic load. Improving hardware (HW) efficiency only would not be enough to reduce the impact of energy consumption; indeed, even though data from network device manufacturers show capacities continually increasing by a factor of 2.5 every 18 months, the energy efficiency of silicon technologies improves at a slower pace, in accordance with Dennard's law (i.e., by a factor of 1.65 every 18 months) [13].

The use of electronic services, such as electronic mail (e-mail), file transfer protocol (ftp), video teleconferencing (VTC), etc., over a wide network has grown significantly over the last decade. These services have traditionally been implemented on wired, or static, networks to provide an effective transfer of data. The reliability of services provided to the user has increased over time to meet current demand. However, the user today requires more flexibility and requires these services in a mobile, wireless environment so as not to be limited to a fixed location. The technological advances have made mobile wireless communications possible, but with many limitations. Improvements in routing protocols are necessary for future mobile wireless communications.

2. ENERGY-AWARE DESIGN SPACE

The energy-aware design space is divided into energy-aware technologies in the data and the control plane. The most crucial energy-related improvements in network equipment design mainly refer to the data-plane of network equipment because this plane usually includes the most energy starving hardware elements. Energy-aware technologies in the data plane refer to the design of novel network-specific capabilities that are able to optimize the power management features (e.g., standby and power scaling primitives) in device architectures, by meeting in parallel their network operational constraints. On a second level, exploiting the equipment's novel green capabilities functions forms another important design area, when considered together with the over provisioned design of network infrastructures; this level of consideration allows the development of local and network-wide control strategies to minimize the overall energy consumption while meeting the operational needs and can be regarded as the design of energy-aware strategies at the control plane. Thus, energy-aware technologies in the data plane can constitute the basis for the design of broader network-wide control strategies for the energy efficient operation of a network as a whole. In this section, these two areas of energy-aware design recognized as the most crucial – energy-aware design of the network device data plane functions and energy-aware strategies' design at the control plane – are further explained. It should be noted that, in this paper, our focus is mainly on the energy-aware technologies in the data plane.

A. Energy-aware design of the network device data plane functions:

According to [15], at the highest level, energy-related improvements in network equipment design can be classified as organic and engineered. Organic efficiency improvements are commensurate with Dennard's scaling law; every new generation of network silicon packs more performance in a smaller energy budget. Engineered improvements refer to active energy management including, but not limited to, idle state logic, gate count optimization, memory access algorithms, I/O buffer reduction and so forth. In this framework and as outlined in [14], the largest part of current approaches for engineered improvements is founded on a few base concepts, which have been generally inspired by energy-saving mechanisms and power management criteria that are already partially available in computing systems. These base concepts for energy efficiency in wire-line networks can be classified into Reengineering,

Dynamic Power Scaling (DPS) and Sleeping/ standby approaches. Re-engineering approaches aim to introduce and design more energy-efficient elements for network device architectures, to suitably dimension and optimize the internal organization of devices, as well as to reduce their intrinsic complexity levels [16]. The dynamic power scaling of network/device resources is designed to modulate the capacities of packet processing engines and network interfaces to meet the actual traffic loads and requirements. Power scaling can be performed using two power-aware capabilities, namely, dynamic voltage scaling and idle logic, which both allow the dynamic trade-off between packet service performance and power consumption. Finally, sleeping/standby approaches are used to smartly and selectively drive unused network/device portions to low standby modes and to wake them up only if necessary. However, because today's networks and related services and applications are designed to be continuously and always available, standby modes have to be explicitly supported with special proxying/virtualisation techniques that are able to maintain the ''network presence'' of sleeping nodes/components and to guarantee a short ''wake-up'' time. These approaches are not mutually exclusive and research efforts will be needed in all of these areas to effectively develop next-generation green devices.

B. Energy-Aware Tradeoffs:

As previously sketched, LPI and AR have different impacts on packet forwarding performance. Fig. 1 shows how AR [Fig. 1(c)] causes a stretching of packet service times, while the sole adoption of LPI [Fig. 1(b)] introduces an additional delay in packet service, due to the wake-up times. Moreover, preliminary studies in this field [2] showed how performance scaling and idle logic work like traffic-shaping mechanisms by causing opposite effects on the traffic burstiness level. The wake-up times in LPI favor packet grouping and then an increase in traffic burstiness

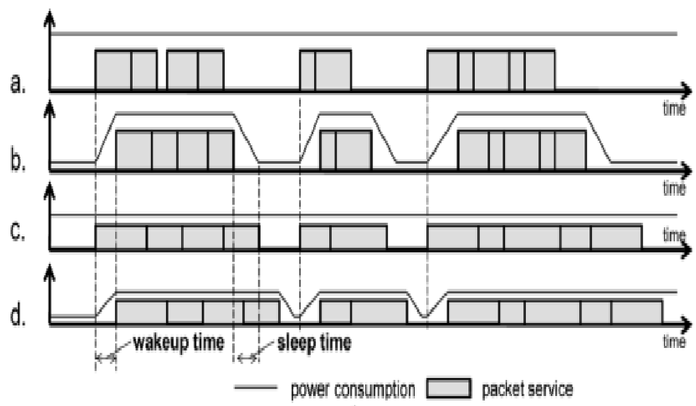

Fig. 1. Packet service times and power consumptions in the cases with: (a) no power-aware optimizations, (b) only LPI, (c) only AR, and (d) AR and LPI.

While service time expansion in AR favors burst untying and consequently traffic profile smoothing. Finally, as outlined in Fig. 1(d), the joint adoption of both energy-aware capabilities may not necessarily lead to outstanding energy gains since performance scaling causes larger packet service times and consequently shorter idle periods. It is worth noting that the overall energy saving and the network performance strictly depend on incoming traffic volumes and statistical features (interarrival times, burstiness levels, etc.). For instance, idle logic provides top energy and network performance when the incoming traffic has a high burstiness level. This is because less active–idle transitions (and wake-up times) are needed, and the HW can remain in a low consumption state for longer periods.

C. Power management support:

Power management is a key feature in today's processors across all market segments. While the ACPI provides a well-known standardized interface between the hardware and the software layers, processors use different internal techniques in order to reduce their energy consumption, by exploiting the basic idea that systems do not need to run at peak performance all the time. This is usually accomplished by tuning the frequency and/or the voltage of processors, or by throttling the CPU clock (i.e., the clock signal is gated or disabled for some number of cycles at regular intervals). Decreasing the operating frequency and the voltage of a processor or throttling its clock, obviously allows reducing power consumption and heat production at the price of slower performance.

ACPI technology introduces two main different abstractions for power saving mechanisms, namely performance and power states (P and C states), which can be individually employed and tuned for each core in the largest part of today's CPUs. Regarding the C states, C0 is an active power state where the core executes instructions, while C1 through Cn power states are sleeping or idle states, where the core consumes less power and produces less heat.

While in the C0 state, ACPI allows the performance of the core being tuned through P state transitions. P states allow modifying the operating energy point of a core by altering the working frequency and/or voltage, or throttling its clock. Thus, using P states, a core can consume different amounts of power while providing different performance at the C0 (running) state. At a given P state, a core can transit to higher C states in idle conditions. In general the higher the index of P and C states is, the less will be power consumed, and heat dissipated. Each processor model generally provides a fixed number of C and P states for all included cores. As already shown in [20], the instantaneous power absorption of the i-th CPU core working with a fixed pair of ACPI states {Cy,Px} can be summarized as follows:

$$\varphi i(t) = \begin{cases} \varphi idle\ (Cy) & if\ idle \\ \varphi active\ (Px) & if\ \ active \end{cases} \qquad (1)$$

where φidle(Cy) and φactive(Px) represent the power consumption when the core is in the Cy state, and when active in the Px state, respectively. The relation $\varphi active$(Px) >> φidle(Cy) is generally maintained. A larger y index of the selected Cy state correspond to a lower φidle(Cy) value. However, the time needed to wake up the core and to enter the C0 active state increases with the y index. It is worth noting that we will not consider in this paper C states deeper than the C1, also because such states require considerable wakeup times (larger than 200μs) that may not be suitable with common performance requirements for packet forwarding.

3. THE IMPACT OF ENERGY PROFILE MODEL

This section introduces the analytical framework for modeling the impact of energy adaptive technologies and solutions for network devices under investigation by the ECONET consortium. This modeling framework is an extended version of the one proposed in [21] and aims to predict the energy gains achievable by using both standby and dynamic power scaling primitives. In the case of DPS primitives, both idle logic and adaptive rate are explicitly considered.

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$$\Phi_{amax} = \Phi \qquad (2)$$

$$\Phi_{amin} = \Phi[\varphi_{ctr} + (1-ß)\varphi_{data} + (1-k)\varphi_{cool}] \qquad (3)$$

$$\Phi_{s} = \Phi[\varphi_{ctr} + (1-\alpha)(\varphi_{data} + \varphi_{cool}] \qquad (4)$$

A. The AR model:

The intrinsic nature of AR primitives leads the device to work with a finite, discrete set of stable HW configurations (in terms of input voltage, clock frequency speed, etc.), generally referred to as the ‘‘state’’. Depending on the HW technology in use (ASIC, FPGA, etc.) and on the implementation of AR primitives (e.g., dynamic frequency scaling – DFS, dynamic voltage scaling – DVS, dynamic frequency and voltage scaling – DVFS), the relationship between energy consumption and performance with respect to AR states may exhibit different trends (e.g., linear, quadratic, etc.).The service time expansion in AR favors burst untying and consequently traffic profile smoothing. Starting from the previous considerations, to estimate the maximum energy consumption in the sth power state,

We apply the following relationship:

$$\mu^{(s)} = s^{-1}(s+1) \qquad (5)$$

B. The LPI model:

An implementation of ALR would entail an Ethernet interface having two physical layers and switching between them. The time to switch between physical layer implementations was deemed to be a major issue, resulting in an alternative LPI [18] proposed by Intel. LPI is the approach specified in the IEEE 802.3az standard and currently allows a 10 Gbps link to wake up in less than 3 μs. Working on similar platforms, Intel researchers [17] specifically focused on LPI primitives and performed a comprehensive study of the impact of transition times on LPI as a function of the load. They showed that, as the transition times shrink from a value of 10 ms to 1 ms and then further to 100 ls, the time spent sleeping at 30% load goes from 0 at transition time of 10 ms to 40% when this time is 1 ms and to 70% when the transition happens in 100 μs.The BAU energy requirement of the entire network infrastructure can be easily expressed as:

$$E_{BAU} = \Gamma.\Omega \qquad (6)$$

To estimate the additional share of HW entering standby modes due to green traffic engineering as follows:

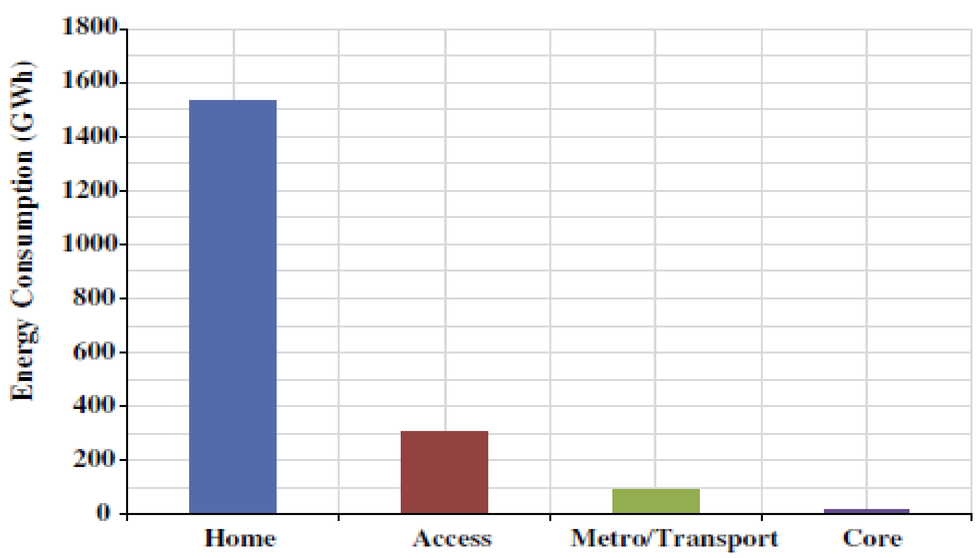
$$\theta_{\alpha} = \theta_{red} + (1-\theta_{red})I_4\delta \qquad (7)$$

The energy consumption of the entire network infrastructure with green technologies (GT) enabled can be easily expressed as the energy consumption of sleeping HW elements and active ones:

$$E_{GT} = [\theta_{\alpha}I_4\varphi_s + (1-\theta_{\alpha})I_4\varphi_{real}].\Gamma \qquad (8)$$

4. THE OVERALL GAINS WITH THE GREEN TECHNOLOGIES FROM THE ECONET PROJECT

The yearly energy consumption in the BAU scenario is estimated by Eq. (4) Fig. 2 shows the yearly energy consumption for the BAU scenarios decomposed per network segment. Most of the energy consumption for the Telecom Italia reference scenario is in the home network. In the GRNET reference scenario, as one can expect, most of the energy consumption is in the core segment. Using Eq. (5), the energy savings gains between the energy consumption estimated by the model including the DPS and stand-by primitives and the BAU scenario.



(a) TELIT

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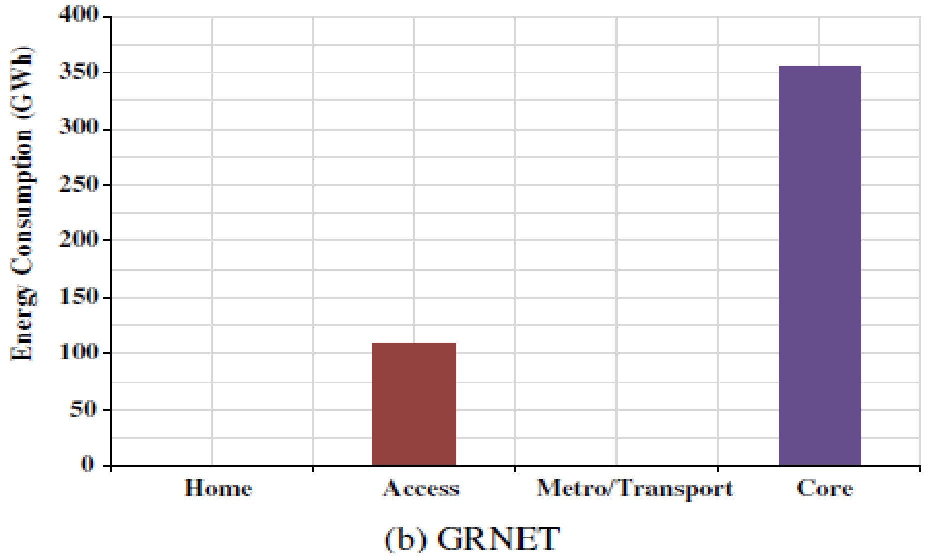

Fig. 2. The yearly energy consumption estimation for TELIT (a) and GRNET b) home, access, metro/transport and core networks in the BAU scenario.

From the results of these figures we can outline how the energy gains exhibit negligible differences between the working day and a holiday. In the Telecom Italia scenario, the largest part of the percentage savings is in the metro/transport and core networks, while the minimum is in the access network.

5. COMPUTER SIMULATION RESULT

NS2 is network simulation and modelling software that predicts performance of networks through simulation and emulation. Simulation software can supports real-time simulation for models of 4000 nodes. Network simulator having the speed in which enables software in-the-loop, hardware-in the-loop and network emulation. Simulator having the Model Fidelity facility it can offers highly detailed models of all aspects of networking. This ensures accurate modelling results

Table I Topological Data (Average Figures) For The Grnet Network

Network part	**Network topological index**	**Value**
Home access	number of customers per DSLAM	640
	link utilisation when a user is connected	10%
Core, transport and metro	redundancy degree for metro/ transport devices	13%
	Redundancy degree for core devices	100%
	Redundancy degree of metro/ transport links	!00%
	Redundancy degree of core device links	50%
	Link utilisation in metro networks	40%
	Link utilisation in core networks	40%

Network simulator offers unmatched platform portability and interface flexibility. Network simulator run on a vast array of platforms, including Linux, Solaris, Windows XP, and Mac operating systems, it can run both 32 and 64 bit computing environments. Table I shows the parameters for new simulation design of the scenario for different protocols with varying the number of nodes.

Table II Simulation Parameters For Energy Based Performance Analysis

Simulator Parameters	
Mac Type	**IEEE 802.11**
Protocols under studied	DSR, AODV
Transmission range	600m
Number of nodes	10 to 30
Traffic type	CBR,FTP
Antenna	Omni directional
Node Speed	10m/s
Propagation model	Two Ray Ground
Channel Frequency	2.4 GHz
Simulation duration	100 s

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A. Snapshot of Simulation:

The simulations of energy model were performed using Network Simulator [19]. The traffic sources are CBR (continuous bit rate). The source-destination pairs are multiplying randomly over the network. The mobility model uses random waypoint model‟ in a rectangular filed of 1500m x 1500m and deploys 6 nodes. During the simulation, each node starts its journey from a source node to destination node. This process repeats throughout the simulation, causing continuous changes in the topology of the underlying network. Fig. 3 Shows the running simulation of snapshot when we applying CBR (1- 6) nodes and AODV routing protocol.

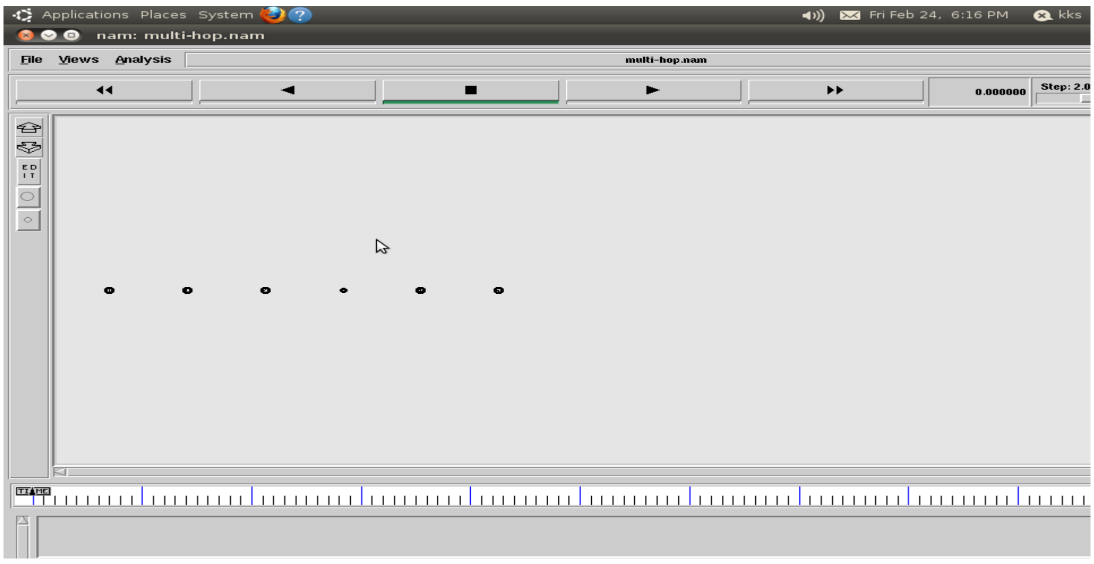

Fig. 3. Snap shot of Network Animator in Action for applying AODV Protocol using 6 nodes.

Initially 5 nodes are created in Network Simulator and energy transmitted between nodes in network from source nodes to destination nodes.

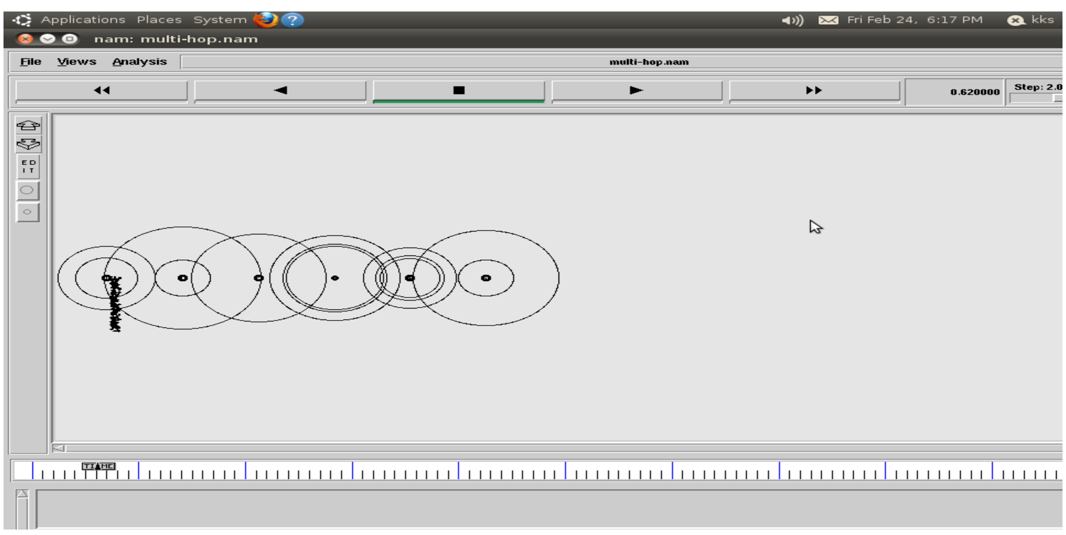

Fig. 4. Snap shot of Network Animator for data is transmitted between nodes.

Fig. 4 Shows the running simulation of snapshot when we applying data (1- 6) nodes and AODV routing protocol. These protocols are AODV and DSR with the channel frequency 2.4 GHz. The node speed is 10 m/sec and each simulation lasted 30 seconds simulation.

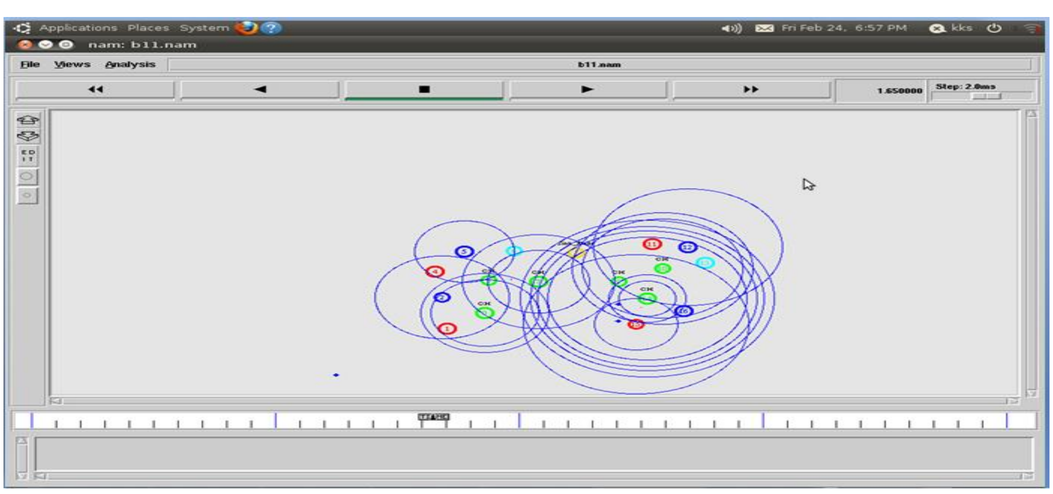

Fig. 5. shows data transmitted from source to destinations

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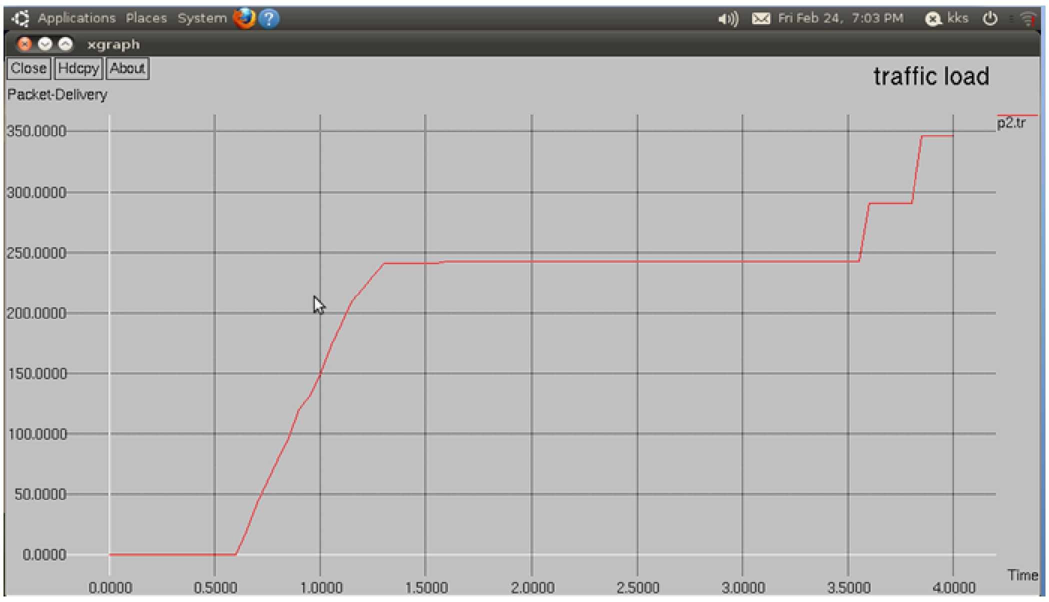

Fig. 6. shows that number of packets vs. cluster throughput

We obtained the number of scenarios in Network simulator with varying 12 nodes selected randomly over a 1500X1500 topology area and taking different routing protocols which we are consider in our simulation. Fig. 5 shows data transmitted from source to designations through cluster head.

This first graph Fig. 6 shows that number of packet delivered from source to destination and cluster throughput may be measured from graph

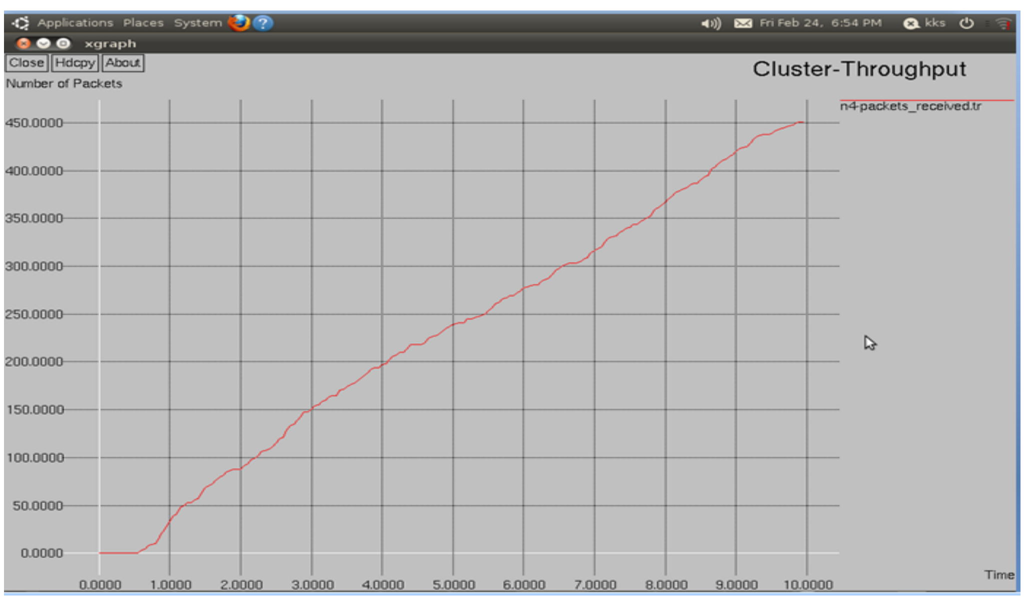

Fig. 7. shows packet delivery ratio

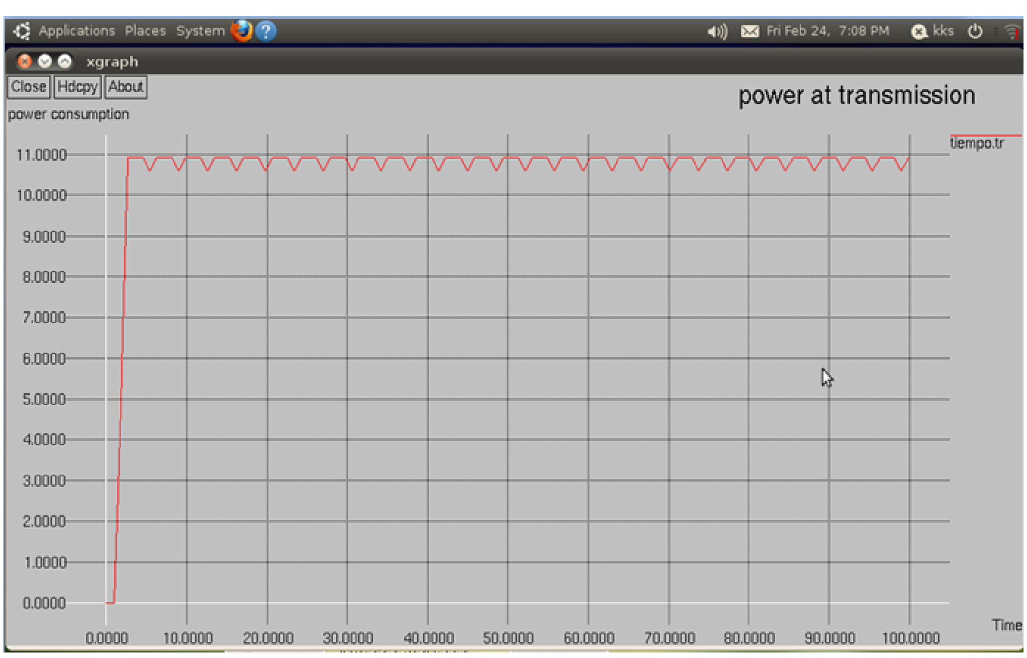

Fig. 8. shows power consumption at transmission

Fig. 7 shows the packet delivery ratio AODV routing protocol energy consumption without any data being sent. Each jump on the curve depicts when cluster heads are being reconfigured. The next graph Fig. 8 shows the power consumption at transmission end having data sent from source. The curve represent Active-Sleeping time to be the lowest for energy cost and Active-Wake Up time to be the most expensive .

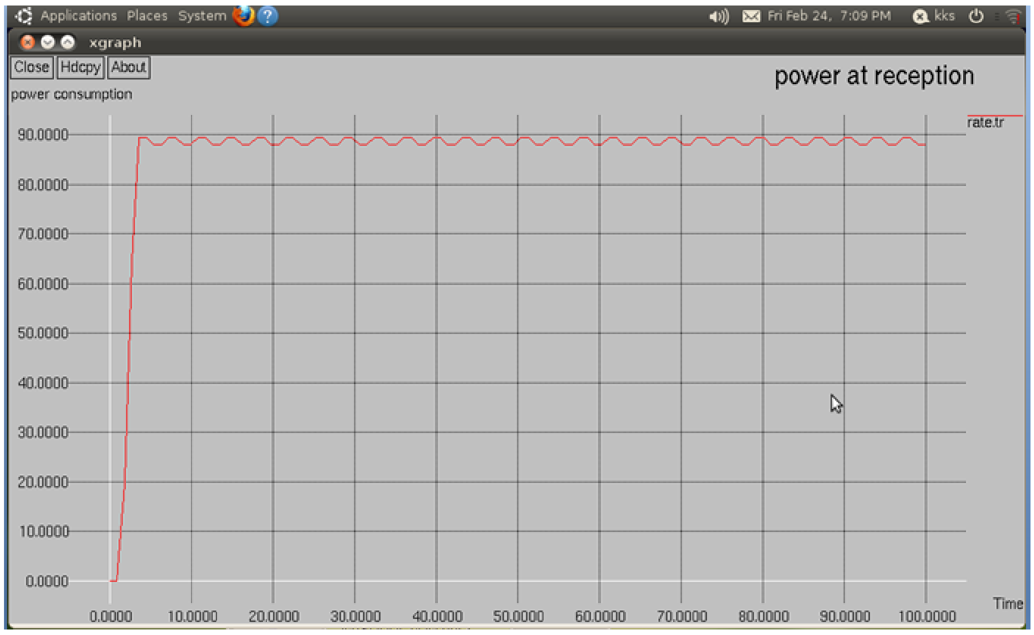

Fig. 9. shows that power consumption at reception

The last graph Fig. 9 shows that power consumption at reception and the curve represents the idle mode when data is transmitted continuously and when no data is transmitted it goes to sleep modes and when again data is transmitted it goes to wake up mode and this process may occur continuously.

6. CONCLUSION AND FUTURE WORK

We observed that Energy saving is an important optimization objective in MANET, the energy consumed during communication is more dominant than the energy consumed during processing because of Limited storage capacity, Communication ability, computing ability and the limited battery are main restrictions in networks. By the observations we compare that the impact of energy constraints on a nodes in physical layer and application layer of the networks that AODV offers the best combination of energy consumption and throughput performance. The next step is to define functions that take the simulation variables as parameters instead of hard coding the values. Also, direct comparisons between alternate routing protocols, alternate sensor energy models, alternate topologies, and multiple base station situations should follow the work accomplished by this project.

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