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GREEN NETWORKING USING MULTIPLE PIPELINE SYSTEMS

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ABSTRACT

Green networking is the practice of using energy efficient networking technologies and minimizing resource use by networking devices whenever and wherever possible. The main goal is to control the power consumption of devices, and provide best way to distribute traffic load among them. The current study envisages to dwell on the concept of packet processing engines which are functionally utilizing the concept of parallel processing of input traffic within the hardware and depending upon the maximum capacity of the system. The system focuses on energy-aware devices able to reduce their energy consumption by adapting their performance according to the network requirements. Green networking technologies like Adaptive Rate (AR) and Low Power Idle (LPI) are implemented. The concept addresses logically the streamlining of processes using interventions both at hardware and software level resulting in a reduced consumption of energy in networking devices.

Keywords: green networking, packet processing engines, adaptive rate technology.

1. INTRODUCTION

The Information Technology Industry has grown exponentially over the last few decades into its present stature. The activities of the industry are typically in terms of hardware that has the capacity to handle the expected loads and software, which typically provides the framework for all operations to be handled in a systematic manner. With the growth in the industry, efficiency has become the key to organizational profit, efficiency, and growth. To achieve these in a sustained manner, all efforts have to be made to develop systems and sub-systems that are individually and collectively efficient and fail-safe. Power saving devices for network operations typically are designed to handle the maximum possible traffic in the worst case scenario of operations. This however is a predicted maximum which is seldom reached in routine operations. Since the system is designed not to fail even when the maximum load is being handled, it utilizes a higher level of energy and also has a real time backup for the same. This could easily be handled by developing smart systems which would utilize energy based on the load being handled in a scalable, programmable sub-system. This would ensure that when less traffic is being handled, the system is in a partially working state. As and when the traffic ramps up, the energy required also is enhanced in a step ladder format. This would ensure saving energy most of the time and yet be ready for peak output using the maximum possible energy requirements of the system. However for such a system to work, there would be a need for switches that get actuated at a particular level of traffic and sleep in absence of the traffic. A short reaction time for such systems is absolutely vital. The success of such a system would depend on a complete understanding of the individual components and their individual energy consumptions, an appreciation of how certain parts of the system can be bypassed when not in use (reducing their energy consumption to near zero), using smart materials which dissipate heat in a more efficient manner, system indicators of functional and sleep modes and an integration of the new algorithms to the existing energy hungry systems. There are two basic green networking technologies used: Adaptive Rate Technology (AR) and Low Power Idle Technology (LPI). Adaptive Rate (AR) is used to reduce the traffic load on each device individually by routing the packets through multiple paths to reduce the load on single paths. Low Power Idle (LPI) is used to put devices into low power or sleep mode when they detect periods of no traffic or less traffic and then rapid wake when data is transferred again to them.

2. GREEN NETWORKING TECHNOLOGIES

Green networking is the process of reducing the power consumption of networking devices such as routers and switches by making them more energy efficient. This involves optimal use of resources and routing methodologies to reduce traffic through devices and to route it in a way that conserves energy, bandwidth and indirectly leads to a reduction in the cost of operations of the network. This is in line with the emerging concerns of people in the field of Information Technology in terms of reducing energy consumption and using sources of energy in a more efficient way to increase its availability for the future generations.

Consolidation of the existing devices and its applications form the prime method of green networking. This involves a multifactorial change, one on the hardware side which becomes more efficient and hence has less energy consumption and secondly on the software side, which if adequately handled using the tenets of virtualization can lead to optimal utilization of energy resources, thereby complementing the gains made by hardware optimization. Extension of the same concept outside the immediate shell include optimization of buildings that house the hardware, diverse and remote locations of hardware systems and an apt use of energy matrices in an Information Technology set-up. The same concepts can be applied to other functional zones in the premises of the offices.

An important concept to appreciate is that of an exponential increase in the quantum of data that is being generated and transmitted with every iteration of advancement of technology. In effect, this leaves the previous data capacities inadequate. Any progressive setup has to plan for the exponential rise in data traffic while taking care of minimizing the energy requirement by making future-ready and energy efficient systems. The need for increasing quantum of data is not only understandable, but also expected since newer computational devices process more and generate more data using advanced algorithms.

The need for checking the energy consumption will have to keep pace with the need to generate and process more data. Eventually, a technological innovation or a shift in dimension of our understanding of the concept of extensive data management shall only provide implementable solution for the problems that are staring us in the eye. The need to seek solutions in the niche area of green networking are not only to address the problems that are being faced but also to provide an energy efficient robust platform for the generations of Information Technology professionals to come.

a) Need for green networking

Due to the massive amounts of pollution caused by the Information Technology Industry, it is absolutely essential to embed Green Networking Technologies into all the devices that are used regularly to control the energy consumption and to cut the costs caused by these devices. It has been shown that the amount of Greenhouse Gas Emissions caused by the Information Technology Industry is 2% of the entire world's emissions of greenhouse gases. This amount may seem nominal at first glance, but it is comparable to the greenhouse gas emissions caused by the airline industry.

Due to the massive amounts of devices that humans are surrounded with, it is important to realize that each of these devices consumes energy and contributes to the pollution. An insignificant reduction in the amount of energy consumed by these devices can cause a huge difference in the overall energy consumption by the devices all over the world. This can effectively reduce the amounts of pollution and energy consumption by the Information Technology, and also reduce the amount of capital that most industries and companies spend to supply power to these devices.

b) Adaptive rate (AR) technology

Adaptive Rate (AR) is a green networking technique used in streaming traffic over computer networks. It involves adapting the traffic flow through a networking device based on the available resources and network speed.

In the existing system, work load is given to a single pipeline processing system. This leads to higher energy consumption and high loads and traffic on rush hours. It does not balance the workload among multiple devices and hence, does not minimize the energy consumption of pipeline processing systems. This leads to some devices handling large amounts of load while others not being used to their optimal capacity. This can cause strain on some components of the network and cause devices to malfunction due to overuse or under-use over a period of time. Hence each device in the network must be used equally by dividing the incoming traffic load among these devices.

Implementation of Adaptive Rate (AR) green networking technology is done by dividing the network into multiple pipelines and implementing a scheduling algorithm on incoming packets to distribute them among all of these pipelines. The Firefly Algorithm is used to for scheduling the flow of packets in each pipeline based on the size of the packet and the capacity and availability of the pipeline.

Firefly Algorithm has been proved to be more efficient, less time consuming and more accurate compared to other methods such as Particle Swarm Optimization (PSO).

c) Low power idle (LPI) technology

Low Power Idle (LPI) is a green networking technology that involves reduction of power consumption by networking devices. It involves the device going into low-power or sleep mode when it detects longer periods of no traffic. Networking devices are designed to handle maximum possible loads. Due to this, these devices consume high amounts of power even when they are handling smaller loads. By going into sleep or low power mode while not being used, these devices can lead to reduction in power consumed. In a world with possibly billions of networking devices with more being added on every day, a reduction in power consumption by each device by even a small amount will lead to a massive decrease in the energy consumed by these devices as a whole.

For every device, the idle time can be estimated by applying mathematical optimization techniques. After estimating all possible constraints, procedures like Mixed Integer Linear Programming (MILP) can be applied to estimate the periods of low power for the device. The device can then go to sleep or Low Power Mode during these periods to reduce its power consumption.

d) Implementation of green networking technologies

When Green Networking Technologies such as Adaptive Rate and Low Power Idle were implemented, the following results were obtained. The energy consumption of networking devices with and without Green Networking Technologies is shown. The power consumption (y-axis) was plotted with time on the x-axis.

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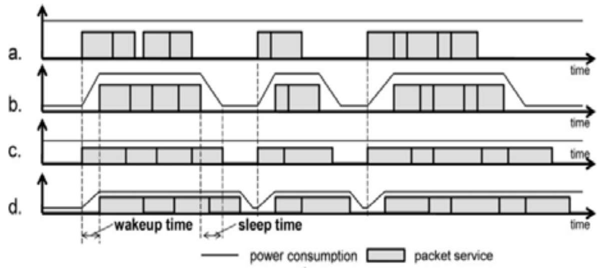

Figure-1. Energy consumption in (a) No green networking technology implemented, (b) Low power idle technology implemented, (c) Adaptive rate implemented, and (d) Both adaptive rate and low power idle technology implemented

In the given graph, the grey areas represent transfer of packets and the lines represent power consumption for-

(a) No Green Networking Technology implemented
(b) Low Power Idle (LPI) Technology implemented
(c) Adaptive Rate (AR) Technology implemented
(d) Both Adaptive Rate (AR) and Low Power Idle (LPI) Technologies implemented

This shows that these technologies (Adaptive Rate and Low Power Idle) implemented both individually and together lead to a reduction in the consumption of power over time. Considering the number of networking devices all over the world, even a small reduction in this consumption of power can lead to a large amount of power being saved, and consequently costs being reduced.

When Green Networking Technologies are implemented, the time taken to transfer the packets or data is reduced. This leads to a reduction in the power taken or the energy consumed by the device. This causes lesser pollution to the environment and effectively reduces the expenditure on power caused by these devices.

3. FIREFLY ALGORITHM

Firefly Algorithm is a scheduling algorithm proposed by Xin-She Yang. It is a nature inspired algorithm based on the behavior of fireflies. Fireflies use their flashes to attract other fireflies around them.

The intensity of the shine of the flash of the firefly can be viewed as the function or parameter with which the comparison of all objects is done for the optimization process. There are three assumptions made in the firefly algorithm -

(a) All fireflies are considered to be unisex. Hence any firefly can be attracted to any other firefly.
(b) Fireflies with dimmer flashes are attracted to fireflies with brighter flashes.
(c) The brightest flashing firefly (that attracts all the others and cannot be attracted by any other firefly) can move randomly.

When Firefly Algorithm (FA) was compared to Particle Swarm Optimization (PSO), it was found that Firefly Algorithm was faster, more efficient and more accurate. It also has lower Standard Deviation and Fewer Errors.

In our system, the size of the pipelines is considered to be the flash of the firefly. Based on their size, the packets will go to the pipeline that has a larger size. Hence each packet goes to the pipeline that has a larger size (Brighter firefly). This causes the packets to be transferred through the pipelines without blocking them due to their larger size or more numbers.

4. PARALLEL PIPELINE PROCESSING SYSTEM

In the parallel pipeline processing system, various parallel pipelines combined together work to distribute and handle the large amounts of incoming traffic load. Here, the entire traffic load is distributed across multiple parallel pipelines to transfer the data. This leads to efficient resource use and lower power consumption by devices. Traffic loads are managed efficiently and energy utilization of each device is minimized.

Multiple pipelines are constructed for processing segmented packets to optimize the energy usage of packet processing. A pipeline can be considered as a number of packet processing components linked serially in such a way that the result of one component is the input to be processed by the next component. There are often queues used as buffers for data to be stored while being processed by each component. Since there are multiple pipelines, they can handle larger amounts of loads more efficiently. Multiple devices can be used to provide multiple paths for transfer of data from the source to the destination, instead of a single series of devices being used.

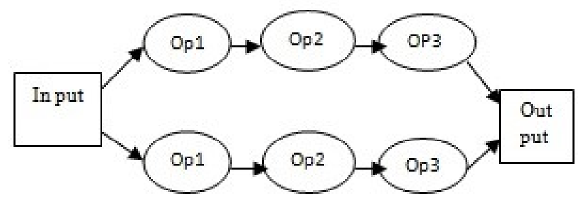

Figure-2. Parallel pipeline processing system.

In the above diagram, two pipelines are used to process the input and generate the output. This causes parallel processing of data and efficient handling of resources. This process effectively reduces the load on each networking device by distributing the incoming data over multiple devices. For two pipelines, each pipeline has to handle only half the load. Hence each device has to process only half of the data it originally had to process. Hence the load on each device is reduced. By increasing the number of pipelines, the load on each pipeline and by extension each device can be further reduced. Since there are lower loads on each device, the power consumption of each device is reduced.

5. SINGLE PIPELINE PROCESSING SYSTEM

In the current pipeline processing system, one pipeline handles all the traffic. This increases the traffic flow through a single pipeline and leads to certain networking devices being used much more frequently than others. This causes these devices to heat up and consume

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more energy while others are not used up to their peak potential and still consume energy. This system is efficient for transfer of smaller amounts of data but causes higher load on devices for larger amounts of data.

This causes devices to malfunction due to being over-used or under-used for their respective capacities. Each device must be optimally used in order to maintain its functionality and reduce the probability of hardware or software issues. In the current system, the most optimal path is found and all the packets or all the data is sent through the particular path. This causes increased load on the given path while other devices remain idle and still consume power, because each device is designed with the capacity to handle maximum rush hour load. For smaller amounts of data, the most optimal path is the best way for transmission. However for the large amounts of data being produced and processed every day in today's world, the most optimal path will lead to congestion, higher traffic loads and higher strain on the devices. It will cause these devices to be used to their peak potential all the time and lead to higher power consumption.

6. IMPLEMENTATION

The system architecture shows how green networking technologies like Adaptive Rate (AR) and Low Power Idle (LPI) can be implemented using firefly scheduling and Mixed Integer Linear Programming (MILP). First, the larger data is segmented into smaller packets. These packets are then forwarded to the scheduling engine. Now, they have to be assigned to the respective pipelines based on their size and the capacity and availability of the pipelines.

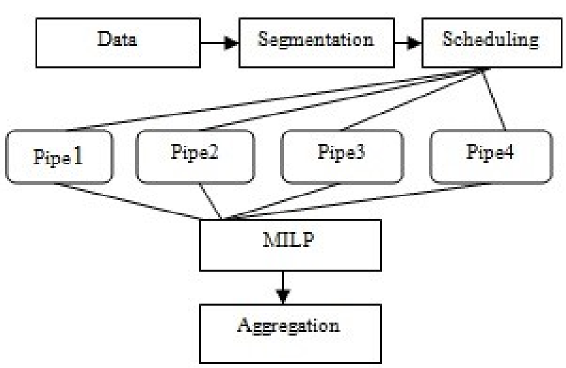

Figure-3. System architecture.

For implementation of Adaptive Rate (AR) Technology, parallel pipelines are used and packets are divided among these pipelines using Firefly Scheduling. This algorithm assigns the packet to the respective pipelines based on their size and availability. Each packet is added to the queue for the pipeline that it is to be transmitted through. The pipelines then process the packets and transfer them. For implementation of Low Power Idle Technology, Mixed Integer Linear Programming is used to find the idle time for each router to put it in low power mode or sleep mode. This reduces the power consumption of each device. The size of the pipelines is predefined. Based on the size of the pipeline, the size of the packet to be transferred and the availability of the pipeline, using firefly algorithm the packet is assigned to a pipeline.

The size of the pipeline is considered as the firefly with higher intensity or shine. The input file that is divided into multiple smaller packets. These packets are then added to the queues of the pipelines based on their sizes. The pipelines transfer the files and the original file is aggregated at the receiving end.

a) Scheduling

The input file is divided into smaller packets based on the size of the available pipelines. How these smaller packets are divided among the multiple pipelines is the process called scheduling.

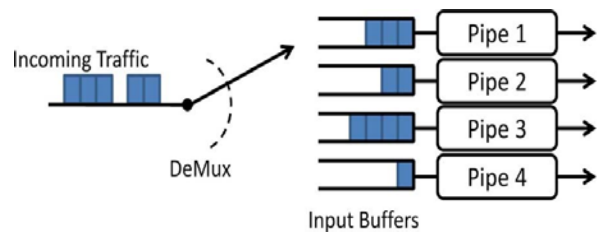

Figure-4. Scheduling in multiple pipelines.

There are various algorithms available to perform scheduling. Firefly Algorithm, Particle Swarm Optimization, First Come First Serve (FCFS), Priority Scheduling are examples of algorithms used for scheduling. Based on the requirements of the system, a suitable scheduling algorithm is chosen and implemented. Firefly Scheduling Algorithm can be used to implement scheduling of packets into multiple pipelines successfully and efficiently.

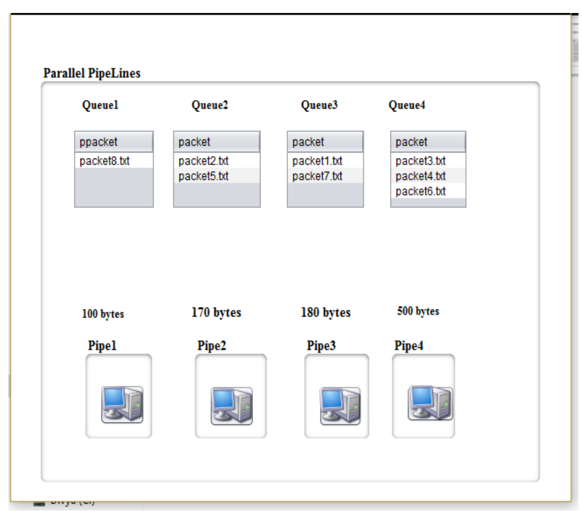

Figure-5. Parallel pipelines.

Hence, by reducing the load or traffic through each device and reducing the power consumption of each device, we can implement both the green networking

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technologies and effectively reduce the power consumed by networking devices.

b) Energy consumption

When the Multiple Pipeline System was implemented using parallel pipelines, the time taken by the pipelines to transfer the packets was recorded. Since the time taken can be considered proportional to the energy consumed by the devices, it is taken as a measure of the energy consumed by the pipelines. When compared to the Single Pipeline System, the Multiple Pipeline System showed a considerable reduction in the amount of time taken to transfer the data, and hence the energy consumed.

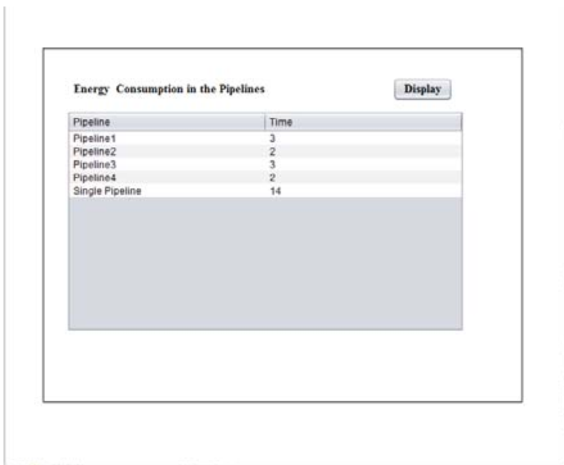

Figure-6. Energy consumption in multiple pipelines.

The time taken to transfer the packet was measured in Milli-Seconds (mS). The result is tabulated and shown in a graphical form.

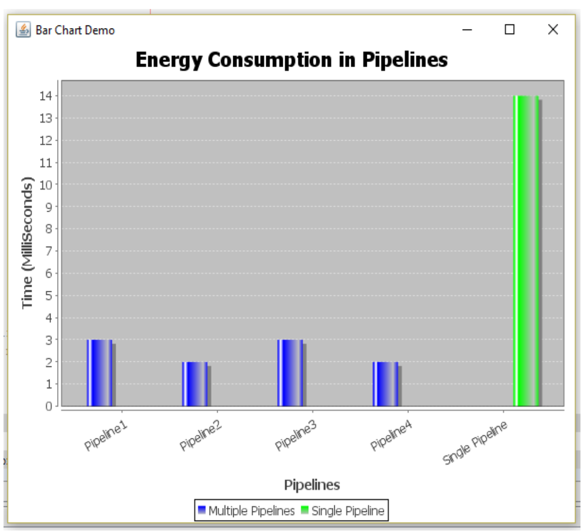

Figure-7. Tabulated comparison between energy consumption in multiple pipeline processing system and single pipeline processing system.

The obtained result shows that when the same file is transferred through both Single and Multiple Pipeline Processing Systems, the Multiple Pipeline Processing System is more energy efficient when compared to the Single Pipeline Processing System, as it takes lesser time to transfer the same data. The overhead in allocation of resources and implementation of algorithms for Multiple Pipeline Processing Systems can be considerable for smaller files but for larger files, Multiple Pipeline Systems are definitely more energy efficient as compared to Single Pipeline Processing Systems.

7. CONCLUSIONS

When both single pipeline processing system and multiple pipeline processing system are implemented and compared, the Multiple Pipeline Processing System is shown to be more energy efficient. This is because it takes lesser time to transfer the same file through a Multiple Pipeline Processing System as compared to a Single Pipeline Processing System. Keeping in mind the overhead taken for allocation of resources and creation of pipelines, and considering the size of the file, the processing system (Multiple Pipeline or Single Pipeline) can be chosen. For smaller files, the existing system may be more efficient due to the allocation of resources and time taken to implement the algorithms.

Reduction of the power consumption of devices is essential in today's world due to the massive amounts of pollution caused and the expenditure done to power the high end networking devices. However the existing system must be kept in mind as there are millions of devices all around the world. The new technologies must be compatible with the older existing systems as replacing all the current devices is not feasible. The networks laid out currently need to be modified to implement Green Networking Technologies.

The concept of green networking is a logical extension of the concern that the Information Technology Industry has towards the environment that we work in. It is also a Corporate Social Responsibility towards ensuring that we do not vitiate the environment more than we already have. Towards this Utopian goal, green networking envisages to provide solutions towards reduction in energy consumption, energy optimization, and optimal use of sub-systems and available resources to achieve the same goals in an energy efficient, non-polluting, future-ready, responsible method.

This however cannot be at a very high cost. The need of the hour is to find implementable cheap yet efficient solutions to address this problem that ails the Information Technology Industry today. It is to be appreciated that any solution has to take into account the existing architecture of systems operations in network-centric operations, a very complex and energy intensive system. Only if we understand the nuances of the system, will we be able to find optimal solutions to this mammoth problem of the Information Technology industry. While we attempt to find solutions, it may not be necessary to re-invent the wheel. The solutions are available in other areas

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of the Information Technology Industry and other branches of applications. We need to adapt the proven concepts into our domain and develop matrices for use specifically in the area of Network Operations.

Green Networking schemes such as Adaptive Rate (AR) and Low Power Idle (LPI) have been proven as a concept without compromising on Quality of Service (QoS). There is a potential gap in concepts and implementable solutions in this field. This is a small step towards addressing this gap in a cogent and logical way. The proof of concept would be in developing such hardware systems which are able to utilize the concepts mentioned above in functioning systems without compromise in output or efficiency. This would require either proving the concept by stimulation over platforms like MATLAB, or by developing scaled models of existing network systems with and without the above interventions and measuring the differences. Extrapolation of the findings would give a reasonable estimate of the potential gains of this intervention.

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