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A New Horizon for Efficient Energy Management Using Green Computing

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Abstract— Green computing is used to denote efficient use of resources which minimize the use of power consumption and increases the energy savings proportionally so to save energy consumption in richly-connected networks. Links which are in core network of backbone network is the gape of multiple cables and line cards named as bundles. In general these bundles are used for reducing energy consumption by shutting down cables. To identify shutting down of cables is an NP complete problem. The solution for this problem is several heuristics concentrates on linear optimization technique which reduces energy consumption under realistic traffic loads and bundled links. Energy conservation algorithm is also proposed that switch off some links in an Internet Service Provider IP-based network to reduce system energy consumption.

Index Terms—green computing, energy saving, backbone network, line cards, bundles, energy consumption, NP-complete.

1 Introduction

IN network research, the carbon footprint of ICT is constantly increasing up to 10% of the global CO2 emissions. Among this 37% of the total ICT emissions are due to telecommunication infrastructures and their devices, while data centers and user devices are responsible for the remaining part of network [1, 2]. Energy consumption of networking devices scales with the installed capacity, rather than the current load. Thus, for an ISP the network energy consumption is constant, instead of traffic fluctuations, since all devices consume always the same amount of energy [3]. Beside this devices are underutilized especially when not in peak hours or in other words when traffic is low. Such scenario represents a clear view for saving energy, since many resources are powered on without being fully utilized, while a carefully selected subset of them can be switched off without affecting the offered Quality of Service. To emphasis on energy savings backbone networks are introduced which play the major role for energy conservation in computer network communication.

A backbone is a larger transmission line that carries data gathered from smaller lines that interconnect with it.

1) At the local level, a backbone is a line or set of lines that local area networks connect to for a wide area network connection or within a local area network to span distances efficiently (for example, between buildings).

2) On the Internet or other wide area network, a backbone is a set of paths that local or regional networks connect to for long-distance interconnection. The connection points are known as network nodes or telecommunication data switching exchanges (DSEs).

The Internet data routes are hosted by commercial, government, academic and other high-capacity network centers, the Internet exchange points and network access points that interchange Internet traffic between the countries, continents and across the oceans of the world.

The devices and facilities in the core/backbone networks are switches and routers [4]. The trend is to push the intelligence and decision making into access and edge devices and keep the core devices dumb and fast. Technologies used in the core and backbone facilities are data link layer and network layer technologies such as SONET, DWDM, ATM, IP, etc. There were several major Internet backbone providers in the telecommunications industry such as Cable & Wireless Worldwide, UUNet, Sprint, AT&T and Verizon which own some of the largest Internet backbone networks and sell their services to ISPs.

The objective of this paper is to propose an optimal solution to reduce energy consumption in backbone networks while still routing all traffic demands on paths with sufficient bandwidth.

To reduce energy consumption in backbone networks an optimal solution is proposed, which shut down the maximum possible cables in bundled links, while still routing all traffic demands on paths with sufficient bandwidth. Such an optimization is NP-complete problem so several heuristics and an energy saving algorithm is proposed. It put some links into sleep mode in IP-based networks, in such a way that traffic demands and bandwidth of the network is not affected. Hence, this algorithm is able to react both to traffic variations and link/node failures. Procedure followed for the same is:

a.) Implement the concept of heuristics for energy saving.

b.) A simple algorithm that describes how to turn off devices which are idle and still make network connected.

c.) Implement Energy Saving Algorithm that include:
   i) Appropriate Node Choice
   ii) Penalty Evaluation

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2 RELATED WORK

2.1 Energy conservation

To minimize energy utilization the network-management system sticks on an optimization issue that considers the fixed network topology, a traffic matrix, and the bundle size as input [6]. Such an optimal solution shuts down the maximum number of cables while still capable of routing all traffic on different paths with their capacity.

2.1.1 Assumptions

1. Inputs to an optimization problem are network topology G (V, E), bundle size B, and traffic demands D. By giving all these three inputs, the network-management system provides a network configuration that makes utilization of very less number of cables and also satisfies all traffic demand.
2. Network-management system “scale up “the traffic demands D to handle variation in traffic, or “scale down" the link capacities c (u, v) to have extra capacity to handle fluctuations in traffic.
3. The result of optimization problems are usually NP-complete, hence another way to formulate the problem in order to maximize the extra capacity for directing the traffic.
4. Such a problem formulate in this way which leads to a simple linear-programming solution that will be used for:
   i) Determine if a given network topology can satisfy all demands.
   ii) Calculating the maximum amount of extra capacity.
   iii) Providing an initial distribution of traffic that can serve as a starting point for heuristics that search for better solutions.

The linear programming formulation is an NP-complete integer linear program. Hence to find feasibility in this context some heuristics are developed.

2.2 Efficient heuristics

The heuristics remove cables in definite order until and unless no further cables can be removed. These heuristics differ in their work as by ordering of cables and by number of cable combinations which they consider it for removal.

2.2.1 Rapid Greedy Heuristic (RGH)

Edges comprises with a number of cables, in this process remove one cable from the edge (u, v) because after the removal, the excess traffic that needs to be rerouted is the smallest. As when the cable gets removed the new link capacities find the new distribution of the traffic [6]. If the problem has a feasible solution then permanently remove the cable otherwise do not remove the cable and mark the corresponding edge as final.

Now no additional cables are removed from final edges. Such process is continuing by identifying the edge with the maximum extra capacity to handle the remaining traffic after that ignored all final edges. This algorithm is easily adaptable due to its simplicity. Disadvantage of this algorithm is that if makes the wrong choice by removing a suboptimal cable from an edge, it will never get backtrack to correct the mistake. Hence the work is get stuck and no proper solution for calculating maximum extra capacity to reroute the traffic.

2.2.2 Extensive Greedy Heuristic (EGH)

To improve over RGH, the EGH algorithm calculates a penalty value for each cable exist in an edge, and removes only that cable which leads to the smallest increase in the penalty. The value of penalty depends upon the path that the excess traffic needs to follow after a cable is removed, and its value get increases as traffic must flow over ever longer paths. The penalty linked with removing a cable is calculated by the difference of the objective value of the linear program which is shown in equation number 1 after and before the removal the objective is to minimize the total flow.

The higher the increase of the objective, the longer the reroute must be. This heuristic is extensive because the penalty allows doing a look-ahead operation on each cable, and then deciding how to proceed. The EGH heuristic is similar to RGH, in this also no edge is marked as final yet the cable with the smallest penalty is removed if the removal results in a feasible solution. Otherwise the corresponding edge is marked as final. Such process is continued by removing cables with the smallest penalty until all edges are final. The penalty solutions choose shorter paths that satisfying demands with fewer links makes it easier to drop cables later on.

2.3 The Energy Saving Algorithm

The main aim of this algorithm is to reduce the network energy consumption by adapting the network according to different traffic variations. Such an algorithm specifies:

(i) Switches off links when they are underutilized, and their absence in the network does not affect the network functionalities.

(ii) Switches on idle links when capacity is required to handle faults, more traffic load or traffic variations.

In this algorithm the process of link switching off/on is decentralized to each node and it takes local decision at random time without coordination with other nodes [7] . Such a local decision require only the knowledge of the current load and energy consumption of incident links and the knowledge of current network topology is defined by a link state routing algorithm [8-10]. This algorithm distribute Link state Advertisement message among the nodes at fixed time interval (ΔLSA) which is selected by network administrator.

2.3.1 Node Choice

Consideration for Node Choice:

1. Any node which is get selected it corresponds to take entry into a specific node configuration which is denoted as Kn, it is the set of all possible configuration for node n.
2. Degree of node n is denoted as d(n) ,hence a configuration is the vector (k1 (n),….,kd(n)),for n incident links that have degree d(n)
3. The configuration kl(n)of a link is a binary variable which indicate state of the link.

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Means k1 (n) =0, if the link is powered off
k1 (n), if the link is powered on
Hence | Kn |=2 d (n)

4. The status of node n is denoted as Sn.
5. Status associated to all links incident to n which have degree d(n).
6. For each link l status sl(n) assume 3 possible value on the basis of link load (ρ) and a load threshold ϕ).

TABLE 1
LINK STATUS DESCRIPTION

Status	Name	Description
ρ= 0	Off	Link powered off or not used
0<ρ≤ ϕ	Normal	Link used but not congested
ρ > ϕ	overloaded	Link congested

7. An utility function is defined as U(Kn,Sn)=c(Kn)+p(Kn,Sn), where c(Kn) is the energy consumption of node n, that is sum over all links in configuration [11-13] Kn and p(Kn,Sn) is a penalty related to configuration that is related on the basis of status and history.
8. Pseudo-code of the node choice in a network graph is given below:

Input: Kold , S
Output: K, Kold,Sold /* Kold and Sold are configuration and status of last choice node respectively.

1. Sold = S // Assigned current Status of node that is selected to last selected node status
2. if lastLSA = = OK : // if receiving of LSA message to last node choice is correct
3. then K* = mink U (K,S) // then for each possible configuration minimize utility function
4. if (check_ connectivity (K*) = = OK) : // If above selection procedure for node is correct means that node is entered into configuration and still network is connected
5. then K= K* // then add that node configuration in all connected links
6. if K ≠ K old // if that configuration does not match with its old detail
7. checked=TRUE // then check connectivity of network
8. else
9. ρ (K*, S)=ρ (K* , S) +β // if a selecting node lead to a network disconnection than associate penalty factor ρ and it will get updated.
10. else
11. K= switch on all // all links are congested switch on all links

In above algorithm of node choice:

a) Step number from 1 to 3 taken for a non congested network state and if its last LSA reported by a congestion then that choice is regretted and node return to its previous configuration otherwise it minimize the utility function.
b) Step number from 4 to 7 defined for non congested network and links are in used
c) Step number from 8 to 10 shows the network disconnection, it is not applied and its penalty is updated with an additive factor β if a violation occurs.
d) Step number 11 lead to network congestion and the node which is selected automatically select the all on state and this choice is not regretted.

2.3.2 Penalty Calculation

The pseudo-code for penalty Evaluation:
LSA Arrival // receiving of LSA message to each node of a network graph.
Input: K ,Kold , S old , ρ // given input as a last choice node configuration and its status with its associated penalty value.
Output: K, ρ // new updated configuration with associated penalty value.

1. If checked = = TRUE : // if network is not in congested state
2. If LSA = = OK : // and the LSA also not reported as congestion
3. For J in K : // repeat the loop for each node which get selected
4. ρ (J , S old) = ρ (J , S old) × δ // if decision does not lead to violation
5. Else :
6. ρ (K , S old) = ρ (K , S old) + β // if it violates and leads to network disconnection
7. K=K old // configuration remain the same and choice is get regretted.
8. Checked = FALSE // leads to network in disconnected state.

The values of penalty is get updated step by step on the basis of history, as by selecting a node n and take decision to enter into configuration K with S status that is followed by LSA leaves the network in critical state the cost associated with that node choice will be ρ (K ,S) i.e. a penalty value. Line number 4 indicates that if decision is taken in state S and there is no violation is reported by next LSA, the cost associated to that choice in sate S is ρ (*, S) get decremented by a multiplicative factor δ≤1.Line number 6 indicates that if decision is taken in state and there is violation and leads to network disconnection then the cost is get incremented by an additive factor β ≥ 0.

3 Experiment and Result

To check the performance of algorithms by using a simulation tool named as network simulator (NS-2) which simulates the network topology.

Module 1: In this module the nodes are connected through wired medium. For maintaining the bandwidth according

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to the heuristics technique the links in the bundled links have been shut off or power down at different time slots which has been shown by energy graph named as energy.tr.

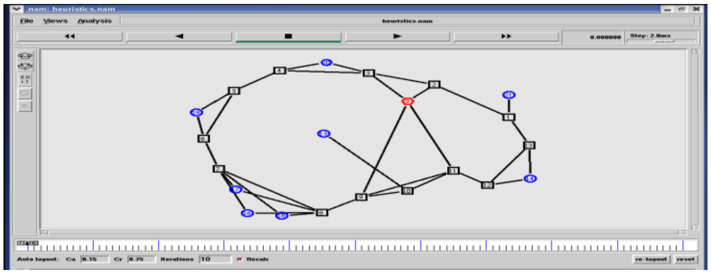

Fig.2: Network topology

Packets transferring:
Node 1 is attached with CBR traffic and UDP agent which consist of 500 packets at interval 0.1 units. As when packets starts transferring from nodes some of the links are up and some of them may be down at different time slots. Therefore, some of packets are getting dropped. Red link indicates no packets is transferred hence that link is put into sleep mode or in down state and black link indicates that packets are transferred from one node to another node which are in upstate.

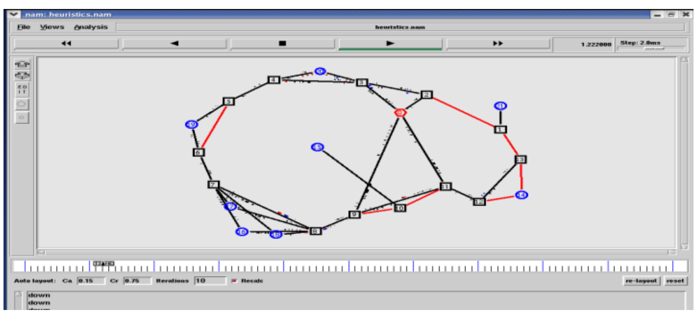

Fig.3: packet transferred between nodes

Packet dropped: If links are shut down, then the packets move towards dropped down links.

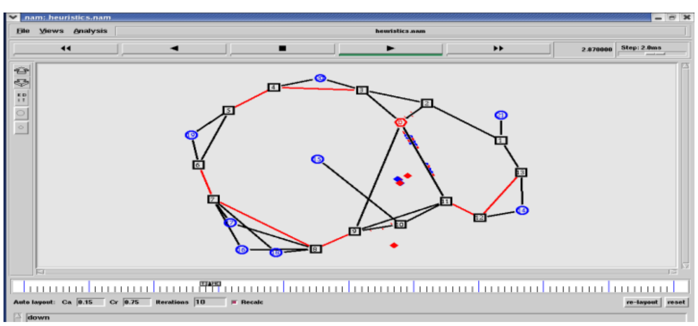

Fig.4: packet dropped between nodes

After Execution: When all the packets are being transferred, links which are in red color indicates sleep mode.

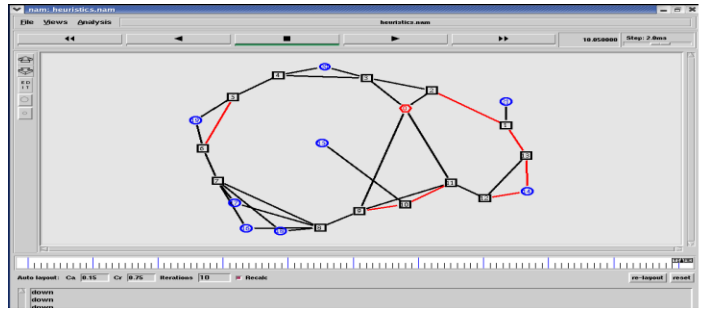

Fig.4: Execution Completion

Graph file: Such graph shows average energy consumption by shutting down some of the links in bundled links at different time slots.

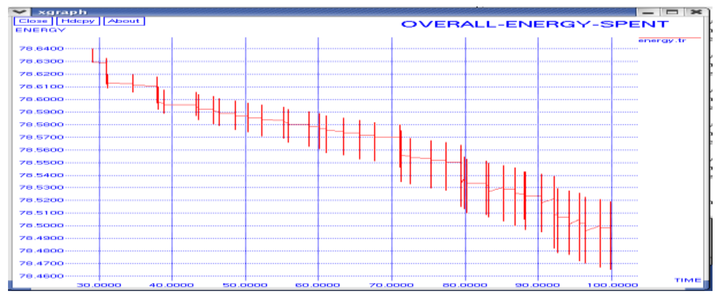

Fig.5: energy graph shows 78% energy consumption

Module 2: Implementation of Green Distributed Algorithm
This is the third module with wired networks constructed under grida algorithm, a novel distributed algorithm to put links into sleep mode in a network. Instead of switching off all the links to a node to make that node shutdown, as done in heuristics technique a single path is alone cut off and the data's are not redirected to the node.

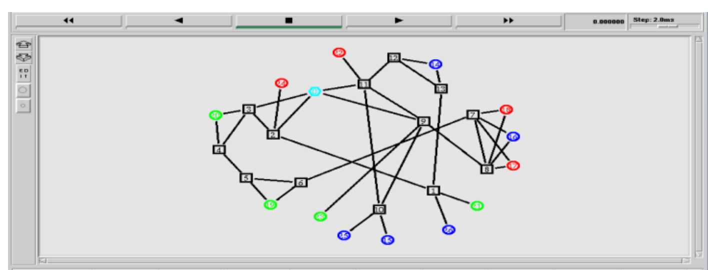

Fig.6: Network topology for an algorithm

Description: This topology includes access nodes(14-26) which are destinations of traffic requests, transit nodes(1-13) performs only switching operations, and a peering node or source node 0.
Simulation: As seen in the simulation the nodes are randomly shut down at intervals thus improving the energy consumption of the network. Nodes 14,15 16,17 18,19 20,21 22,23 24,25,26 are shutdown at regular intervals according to the algorithm and data's are not redirected to the respective nodes.

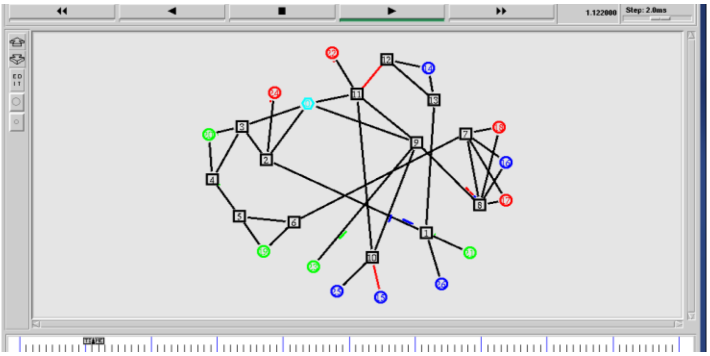

Fig.7: Simulation of topology

After Execution

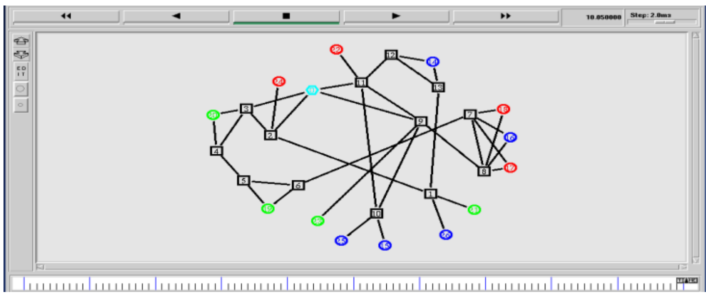

Fig.8: Completion of execution

Energy Graph of Algorithm: Such a graph shows average energy consumption at regular time intervals many nodes are shut down which shows random variations in energy.

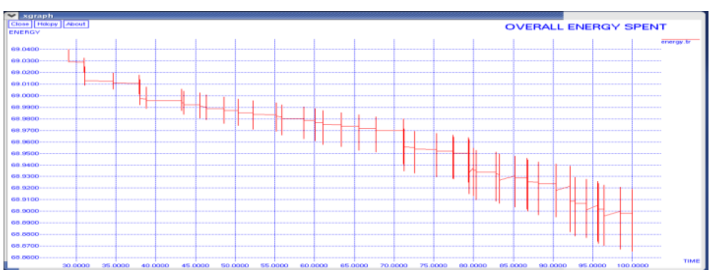

Fig.9: energy graph of an energy conservation algorithm

Module 3: Comparison of above algorithms
This is the fourth module where the energy is compared between the heuristics methods and the grida method. The energy consumption is much less achieved in grida method when comparing with the heuristics technique.

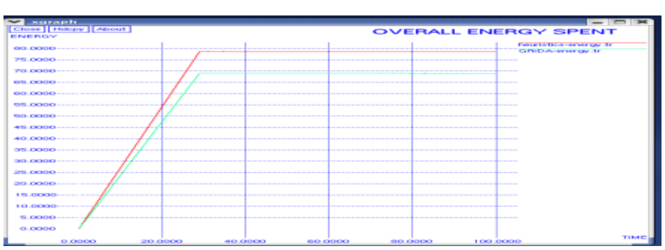

Fig.10: Comparison between heuristics and energy conservation algorithm shows 10-15 % energy saving

RESULT: The above comparison of heuristics technique and energy conservation algorithm shows that less energy is consumed in energy conservation algorithm as compared to heuristics around 10-15% of energy would be saved if grida algorithm is implemented

4 CONCLUSION

The Internet has experienced a remarkable growth in energy consumption. It is evaluated above that some techniques save energy in backbone networks by selectively powering down individual cables of large bundled links. Such a problem is formulated by an integer linear program that is NP complete. So for feasible solution developed with some easy-to-implement heuristic for energy savings. Also one energy conservation algorithm is proposed that is based on penalty evaluation and node choice. Such a solution requires only the exchange of periodic Link State Advertisements in the network.

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