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Multi Layer Network Model in Wireless Network based on Ball Technology Analysis

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Abstract: In order to solve the problems of multi-layer network energy consumption, for the multi-layer network with an IP layer, TDM layer and optical layers 3-layer structure, ITO model is proposed in this paper. The modules sleeping of multi-granularity, traffic multistage grooming and bypass, the route of energy aware and varieties of energy-saving were discussed in the model. According to the specification parameters of actual network equipment to explore how different combinations of network layer, dynamic power dissipation dynamic power of network equipment and modular structure impact on energy optimization of multi-layer network by corresponding experiments. Experimental results show that: The power consumption of the network can effectively be reduced by using the model in this article.

Keywords: Cable network; Energy-saving mechanisms; Optical fiber link; Node

1. Introduction

Due to the rapid growth of demand for network services, the system number and size which network services provide increase explosively, and also the power consumption of network service system is increasing rapidly [1]. The increase of network service system power consumption not only increases the system operation costs, but also restricts the improvement of system performance; meanwhile produce large amounts of carbon emissions. Whether from an environmental point of view or economic point of view, energy control of network service system is becoming an important factor in system design increasingly [2-4].

Wired network energy consumption begun to be valued by people until Gupta and Singh's work, since then, there has been a lot of energy-saving research on wired networks. Bianzino A P and others summarized the wired network energy-saving research works of recent years.

When the wired network was originally designed and deployed without considering energy optimization goals, and more serious is one of two design criteria, over provisioning (over provisioning) and redundancy (redundancy) completely agree with the goal of energy consumption optimizing. The basic idea of excess configuration is that: due to the lack of QoS guarantee mechanism in Intement system configuration, in order to guarantee, it is usually configured according to the system peak load, but when the system load is low, the service capacity is remaining, it means that there is energy waste. The basic idea of redundancy is: In order to protect the system flexibility and fault tolerance, for critical system components, multiple components were deployed to deal with emergency situations. These two design criteria resulted in tremendous waste of network resources and unnecessary energy consumption, with the skyrocketing of network size and network applications, more and more researchers design different techniques and algorithms to overcome the defects of these two designs criteria.

Internet can be roughly divided into the core network and various types of access networks, the network service system connected to the Internet through the access network to provide services. The access networks and the core network this infrastructure include many network devices and communication protocols, to a large extent, this network devices and communication protocols determines the energy consumption of the network layer [5-7]. MPLSover OTN / WDM network and candidate path were used to achieve the routing of IP / MPLS layer, OTN layer and WDM layer, while it lacks the validation of experiments on model.

2. Network Model and Energy-saving Mechanisms

2.1. Network model

Multilayer network model in this paper is composed of 3 network layers: the IP layer, TDM layer and optical layer (see Figure 1). Each node in multi-layer network is usually constituted by a group of network devices, including the IP device, TDM device and optical network equipment. The nodes connected by the fiber optic link, network device in the junction is connected through the physical line (represented in Figure 1 by the solid line) .

There is no direct physical link between network nodes in TDM and IP layers, the virtual path provided by the underlying network is used (like optical paths optical layer provided and TDM and the circuit TDM-layer provided) to establish their own logical link (indicated by dashed lines in Figure 1). Each network layer link collection is generally different (see Figure 1), each network node of the network layer need not set the same, the upper network node set is a subset of the set of lower layer network nodes.

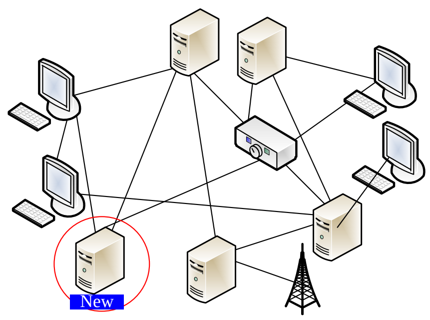

Figure 1. IPover TDM over WDM network schematic diagram

Currently, a modular structure is typically used in the core network equipment the network devices are designed to be composed of machine frame and module card. According to the actual networking requirements, the necessary network equipment chassis is set up by adding the appropriate module card.
The modular design allows flexibility and scalability of network devices can be enhanced to achieve the expansion and upgrade of individual network devices by adding or replacing the module card. In addition, you can also break the capacity of a single device limitation through multi-chassis cluster approach and meet processing demands of massive business.

2.2. Energy consumption analysis

It is assumed in this article that: 1) the used MAC protocol in the sensor network is based on the CSMA transport mechanism; 2) network nodes does not moved after deployment3) sensor nodes have the same initial energy after dispensing; 4) sensor nodes have the same transmission radius ; 5) the network lifetime is defined as the network time which first network node energy depleted.
When a node 1bit data transmitted, the transmission energy Etx= Eele+ Eamp. Wherein Eele represents the consumed energy of non-energy emitting device (frequency synthesizers, mixers, filters, etc.), ηamp is the energy the transmitting device which consumed, the value is:

$$E_{amp} = \frac{\beta R^{\gamma}}{\eta_{amp}}$$

Where β is the constant that related to the hardware, R is the node transmission radius, γ is the path attenuation factor, ηamp for the transmitter magnification. So when a network packet length is L, the energy that the node single-hop transmission consumed can be expressed as follows:

$$E_{lhop} = L(E_{tx} + E_{rx}) = L(E_{ele} + \frac{\beta R^{\gamma}}{\eta_{amp}} + E_{rx}) \quad (1)$$

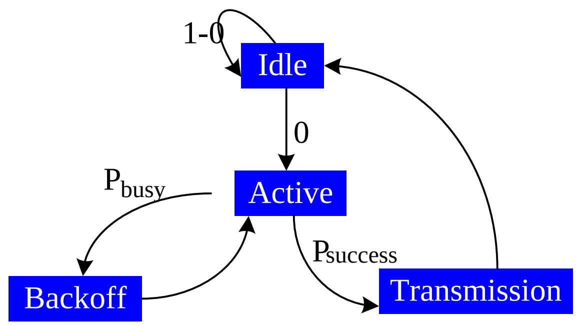

Figure 2. CSMA transmission mechanisms

Wherein, Erx is the energy when node receives the energy consumption per bit.
The energy consumption of transmitted data based on CSMA mechanism is not sure each time; it is related to the number of the number of events triggered in the network and competitive transport nodes at this time. According to this paper, packet is successfully transmitted the expected energy ECSMA to measure the energy consumption of data packet transmission.
There are four sensor nodes state assumed in CSMA mechanisms: 1) idle state I; 2) An active state (carrier transmission detection); 3) T transmission status; 4) B retreat state. State transition is shown in Figure 2.
When the node is between the slot time 1 and the NAV (network allocation value), a slot time is picked in the equal probability at random, the probability of node selecting slot time r P (r) = 1 / NAV. According to CSMA transport mechanism, when N nodes simultaneously compete for the channel, the probability that the node successfully transmits data in slot time r is:

$$P_{success}(r) = C_N^1 P(r)\left[1 - \sum_{i=1}^{t} P(i)\right]^{N-1} \quad (2)$$

2.3. Power consumption model

pd-the power consumption of network devices can be divided into static and dynamic power consumption, the dynamic power $p^t(t)$ is related to actual business load of network equipment t , the static power p^s is a constant which is independent of the traffic load. For modular network equipment, static power consumption is divided into the machine frame power consumption p^c, ply-yarn drill power consumption p^l and interface power consumption $p^t(t)$, that is:

$$p^d = p^s + p^t(t) = p^c + p^l + p^p + p^t(t) \qquad (3)$$

Power consumption of the network node p n is equal to the sum of the power consumption of all network devices in junction, that is

$$p^n = \sum_j p^d(j) \qquad (4)$$

Power consumption of the entire network layer p^{nl} is equal to the sum of power consumption to all network nodes, that is

$$p^{nl} = \sum_i p^n(i) \qquad (5)$$

Power consumption of multi-layer network P is equal to the sum of the power consumption of each network layer:

$$P = p_{ip}^{nl} + p_{tdm}^{nl} + p_{optical}^{nl} \qquad (6)$$

3. ITO Model

If the energy is seen as a system resource, then the management and control of energy consumption can be attributed to the configuration and management of resources, while the allocation of resources will need to be based on business requirements. Therefore, under the network environment, the network energy consumption can be reduced through the control of the network traffic flow and the configuration and management methods of network resources. Here the power consumption optimization problem of multilayer network which is composed of IP layer, TDM layer and optical layers is modeled, and this optimization model named ITO (IP-TDM-Optical) model. ITO model achieved the collaboration between network traffic control and network resource allocation and management, by routing methods to rationally allocate traffic between multiple network layers and in internal network-layer, according to the arrival of the traffic load, network equipment reasonably configure and manage network resources, transfer the idle module into sleep mode in order to reduce network energy consumption. ITO model is based on network flow programming theory, the multi-layer structure of the core network and the modular nature of network devices are considered, and then transformed into a linear variety streaming programming problem and become MILP problem finally.

Sensor networks can generally be described as a connected graph G (V, A). Wherein the sensor node set V = R ∪ S ∪ T, R is the data source sensor node set, S to Sink node set, T is a collection of data relay node (this kind of allocation method only represents the functional division when the data is transmitting, in large-scale wireless sensor networks, other nodes except Sink nodes are likely to be data acquisition node or relay node).

Fig 3 the set of the sensor data acquisition node is assumed that R = {K, D}, the relay node is T = {B, C, E, F, G, H} and Sink nodes S = {I, F}. When a node K collected data and requested to send to the node I, it can choose the path K-B-D-G-I, K-B-E-G-I, K-C-F-H-I, K-B-D-E-G-I and K-B-D-G-I, K-B-E-G-I, K-C-F-H-I, K-B-D-E-G-I this five road. When node D collected data and transmit to node F, there is only a unique path D-E-F.

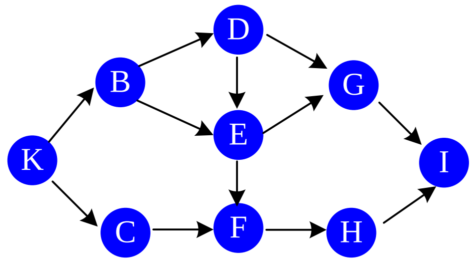

Figure 3. Connection diagram of example network

Considering the computing power and transmission characteristics of sensor nodes in wireless sensor networks, the path cumulative power consumption routing selection mechanism is relatively simple, the route judge of the relay node is completed by the following steps: 1) calculate the size of alternative paths cumulative energy consumption of each path; 2) the packet is forwarded to the minimum cumulative energy path; 3) update the cumulative transmission power consumption in the path for each arc.

In order to make the total power consumption be smallest network based on reflect as much as possible to extend the network lifetime in the optimization model, then the routing policy of smallest cumulative energy path is chosen to transmit. In the ITO model, the goal of multilayer network energy consumption optimization is to minimize the power consumption of multilayer network, i.e. Pmin. Tributary interfaces of TDM equipment and optical network equipment is connected directly to the upper line interface devices, branch line card can not freely assign tributary interface, therefore, the branch line card is included in the considerations of machine frame power consumption, power consumption of tributary interface and upper line interface are calculated together. Since the power of optical network equipment is smaller than the TDM and IP equipment which have the same capacity, while the optical transceiver component is the primary network device of light energy, so the power consumption of optical network device tributary interface (i.e., optical transceiver) is only considered. A linear function is used to approximately represent relations between the network devices dynamic power and traffic load, and the objective function is

$$P_{\min} = \min[n_2^c(u)\bullet p_2^c + n_2^l(u)\bullet p_2^l + n_2^p(u)\bullet (p_2^p + p_1^{bp}) + t_2(u)\bullet p_2^t] + \sum_{i\in N_3}\{\sum_{r\in R}[n_3^l(i,r)\bullet p_3^l(r) + n_3^p(i,r)\bullet (p_3^p(r) + p_2^{bp}(r))] + n_3^c(i)\bullet p_3^c + t_3(i)\bullet p_3^t\} \quad (13)$$

In the model, the representation of the objective function is more complicated and in the large-scale wireless sensor networks, data transmission routing path can be gotten through a series of path detection algorithm; but in the optimization model, by the direct path constraints to solve the model is very difficult. For the problem that such kind of path is difficult to determine, Beckmann proposed to use Frank-Wolf method, for the path traffic which is difficult to calculate in general network flow problem, it can be converted into arc flows into the model which is calculated relatively easily, and the relatively simple "all nothing "(All-or-Nothing) method can be used to solve it.

4. Experimental Simulation and Analysis

4.1. Experimental environment and setup

The mathematical tools GAMS / CPLEX is used to solve problem in simulation experiments. CPLEX is a high performance MILP solver, the branch and bound algorithm of higher execution efficiency is used, by calculating a series of linear programming sub-problems to solve ITO model. The multi-layer network with six node and 16 directed links are used in the experiment. In IP layer devices, Cisco CRS3-4 / S souter specifications are used as a reference, the maximum power consumption is 3080W, forwarding capacity is 560Gbps, the power consumption of the machine frame is 696W, each machine frame can accommodate four line cards, each line card consumes 446W. TDM layer device with Huawei OptiX OSN 8800 specification parameter for reference, the maximum power consumption is 2052W, forwarding capacity is 640Gbps, and machine frame power is 750W.

4.2. Analysis

1) Network layer and multi-layer network power consumption

By adding new routing constraints for each network layer in multi-layer network and the exchange ability of the network layer is forbidden to study each network layer and the role of network layer combinations on the network energy optimization. In addition, it enables business needs of the network layer transmission via single-hop path that the network layer switching capabilities is forbidden, the business will bypass in the underlying network by reducing the network layer traffic grooming capability (that is from multi-hop grooming to a single-hop grooming), So that the purposes of the studying the impact of business dredge and business bypass on network energy optimization is reached. Optical layer , respectively , TDM and IP layers is added the following route constraints, and the network layer parameters ω (a binary number 3) is used to indicate whether start to use these three routing constraints. There will be seven kinds of meaningful combinations obtained; the meaning of each combination is shown in Table1. The experimental parameters η is valued 20%, the seven kinds of above combinations were done simulation respectively, the experiment results shown in Figure 4.

Table 1. The parameters and meanings of network layer

The value of parameter ω	meanings
0(000)	Three network layers has the ability of business switching, that is IP over TDM
4(100)	The switching ability of optical layer is forbidden, that is IP over TDM network
2(010)	The switching ability of TDM layer is forbidden, that is IP over WDM network
1(001)	The switching ability of IP layer is forbidden, that is TDM over WDM network
3(011)	Only optical layer has the switching ability, which is optical network
5(101)	Only TDM layer has the switching ability, which is TDM network
6(110)	Only IP layer has the switching ability, which is IP network

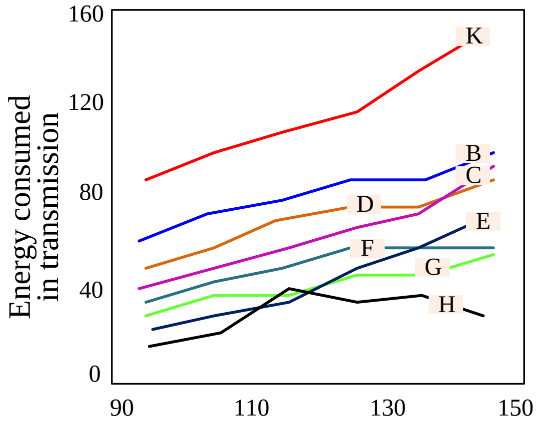

Figure 4. The network power consumption optimization result of different network layer

(1) The impact of traffic grooming and bypass energy optimization. When network traffic is low, the traffic grooming can aggregate business into a small number of link transmission, reducing the active interface line cards and chassis number, so traffic grooming play a dominant role on the network energy consumption optimization. However, because the power consumption of the optical layer is much smaller than the IP layer WDM layer, for optical layer, the energy-saving effect of traffic grooming purposes is very limited, so the power consumption optimization of electrical switching network (ω = 5,6) is better than the optical network (ω = 3), the effect of two

layer networks of pure electric exchange (ω = 4) is better than the optical hybrid network (ω = 1,2). When the volume of business is high, the effect of the traffic dredge on energy consumption optimization reduces. Traffic bypass play a leading role, as the optical network can achieve the business exchange at the wavelength of optical domain, and it has much lower power than the electric exchange, therefore the effect of the optical network (ω = 3) is better than the electrical switching network (ω = 5,6), the two layer networks of opto-electric hybrid (ω = 1,2) is better than two layer networks of pure electric switching (ω = 4).

(2) The impact of the network layer on energy consumption optimization. Different combinations of the network layer have different power optimization results. As Figure4 shown, the three-layer networks 4 (ω = 0) is better than the two-layer networks (ω = 1,2,4), two-layer networks is better single network (ω = 3,5,6), the maximum power consumption difference between different network layer combination is up to 30 %. Compared with two networks (ω = 1,2), the advantage of three-layer network power optimization effects is not clear, The mixed two-layer network of photoelectricity can be a good to have the dredge effect and bypass effect of optical switching effect, additional TDM-layer does not improve the network energy optimization almost, and the energy optimization solution time of 3 -layer network is much longer than the two-layer network. Therefore, considering from the aspects of network power optimization effect and solving time, IPover WDM network is an ideal core network technology.

2) Dynamic power consumption and multi-layer network

Three -layer network (ie, ω = 0) is used to get different values respectively from the dynamic power parameter η, (values were 0 %, 20 %, 40 % ... 100%) to do simulate experiments, the results shown in Figure 5, 6. The results show that the greater dynamic power consumption of network equipment is, the better network energy consumption optimization is, specifically in the following two aspects. First, when the volume of business is same, the dynamic power consumption is greater, the power consumption of the network is lower, when the dynamic power consumption grew from 0% to 100%, the network power consumption reduce averagely 10118W (see Figure 5). Secondly, the greater the dynamic power consumption of network equipment is, the network power consumption proportion in the largest networks during business low peak is smaller (see Figure 6).

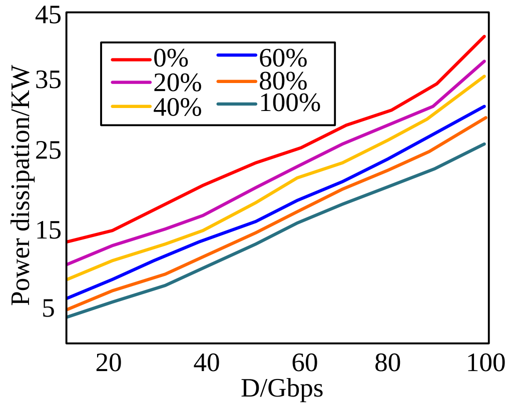

Figure 5. The affect that network equipment dynamic power on energy consumption optimization

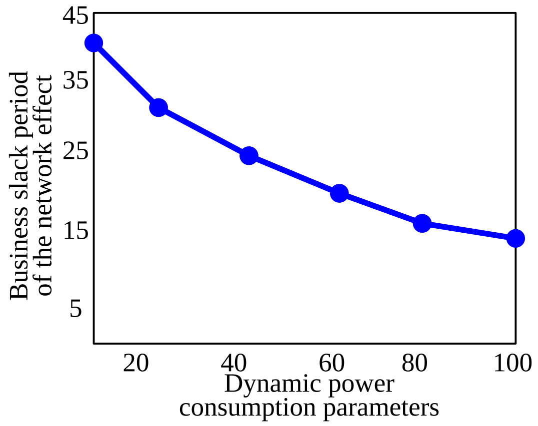

Figure 6. The impact of network equipment dynamic power consumption on network power during business low peak period

3) The modular structure and the network power consumption

The modular design of the network devices will influence the network power consumption optimization. Different network equipment design, the functions on liner card and the machine frame is different, the results lead to the proportion of power between them is not the same. The modular parameter ζ is used to represent the percentage of chassis power consumption pc in chassis and line card power $pc + pl$ percentage, that $\zeta = pc/(pc + pl)$. The dynamic power consumption parameters η is 20%, parameter ζ values 0% , 20% , ... 100% , the simulation results shown in Figure 7 .

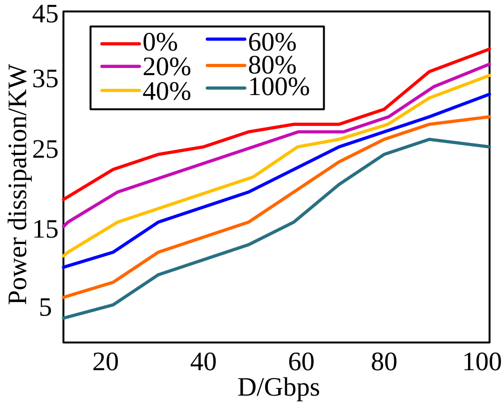

Figure 7. The effect modular of network device structure on energy consumption optimization

The results showed that the smaller the proportion of chassis –power is, the network energy optimization is better, the network consumes less power. When the business needs of the network is small, the effect of network device modular structure on network energy optimization is bigger (maximum up to 13461W). With the increasing demand of service, this effect becomes smaller, and there is a demand for some business value to make the effect reach a minimum value (influence is not more than 2399W). After analysis of the optimal solution, it can be found: t, the conditions to make the effect to be minimal is that: the amount of each node interfaces in network and the use of line cards (ie, the number which is in active state) are very close to the interface and line card chassis with the active state on amount (i.e., the number of equipped one).

It is easy to understand, when traffic is low, there are less amount of the interface and line card chassis to share the power of machine frame, while when the proportion of the machine frame power consumption reduce, the original part power of the chassis transferred to the line cards, and a large number of line cards in sleep, so the network power consumption can be reduced. When the previous minimum conditions is meet, all of the line cards and interface in the active chassis almost are working, and thus the affect of the chassis power consumption proportion on the network has reached minimal. The current average link utilization of core network is low, network equipment with excellent modular design will help to optimize the network power consumption and reduce the energy consumption in network.

The above three experiments comprehensively demonstrate the effectiveness of ITO model. In Figure 2, the network power consumption under the seven values of ω are decreased with the business needs decreasing, when business needs is in low peak (Davg= 10Gbps), the network power consumption can be reduced to the power consumption of the peak business (D a v g 24% ~ 38% = 100Gbps). In Figures 3 and 5, whatever how dynamic power consumption and modular structure change in network equipment, the conclusion is always correct that the network power consumption is reduced when business needs reducing.

5. Conclusion

The traffic multistage grooming and bypass, the route of energy aware and varieties of energy-saving were discussed and the power consumption optimization model of multi-layer network with an IP layer, TDM layer and optical layers is established in this article. According to the specification parameters of actual network equipment to explore how different combinations of network layer, dynamic power dissipation dynamic power of network equipment and modular structure impact on energy optimization of multi-layer network by corresponding experiments. Experimental results show that: The power consumption of the network can be effectively reduced and the network power consumption of service off-peak can be reduced to 24% to 38 % of the service peak period by using this model.

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