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A Peer Management Policy for Energy Efficiency in Mobile P2P Networks

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Abstract

Recently, mobile devices with multiple network interfaces are not only being used in the daily life but also across the entire industry in diverse ways and in many different sectors, including medical, health, education, business, and entertainment. Especially, analyzing the mobile usage patterns of users, there's been an increasing number of services that provide diverse types of content on an Internet-based environment, including video conferencing and VOD streaming services. For these kinds of services, due to the limitations imposed by the client/server architecture which involves going by a base station, the need for P2P is currently being emphasized, which allows direct communication between mobile devices. In order to improve the stability of mobile P2P services, however, there are challenges to overcome, including constraints of wireless communication (such as irregular bandwidth and frequent interrupts in the connection) as well as limitations of the mobile devices themselves (such as limited CPU and battery capabilities), which are classical mobile computing problems.

Accordingly, this paper suggests a peer management policy for mobile P2P environments with high degrees of mobility which is designed to increase the efficiency of data transmission by taking sufficiently into account network characteristics and energy efficiency of mobile devices.

***Keywords**: P2P, Mobile P2P, Energy efficient,Mobile computing,Overlay-multicast*

1. Introduction

With the recent strides made in mobile computing technologies, the mobile P2P network is garnering attention, in which a large amount of data can be transmitted at high speeds over many different types of wireless connections.In contrast to the existing wired network, this type of a network offers the following advantages: it doesn't require additional costs for the construction of the infrastructure; loads can be distributed, which would otherwise be concentrated at a specific server; and it can accommodate a large number of users[1]. Therefore, the P2P streaming technology is being suggested as a new way of transmitting data that overcomes the problems of high infrastructure construction costs of the more traditional types of networks and low scalability of centralized CDNs (Content Delivery Networks) [2].

Meanwhile, as the landscape of video conferencing, UCC, VOD and entertainment grow, mobile users are showing a great tendency of preferring media streaming services. According to the network trend data released by CISCO, for South Korea, mobile video

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content accounted for 59% of all mobile data traffic for 2014, which is expected to further increase to 75% by 2019[3]. Mobile devices that support multiple wireless network interfaces have especially limited battery capacities, and currently research efforts for increasing battery capacities are not really bearing fruit. Therefore, from the aspect of network stability and efficiency, the energy efficiency of mobile devices is one of the most important factors to consider [4-5]. In a mobile P2P network, a parent node plays a central role in the P2P communication because it uses information of adjacent sub nodes[6]. When a disconnect occurs with a sub node as the parent node moves, the topology will need to be reconfigured and this will have an adverse impact on the network stability. Fast movement of the parent node not only involve the problem of reconfiguring the participating nodes but it is also closely related to its battery consumption.Furthermore, for mobile devices that support multiple wireless network interfaces, there will be differences according to their communication schemes and network interface schemes. For example, comparing 3G with Wi-Fi, there are differences according to transmission speed, network coverage, and amount of energy consumption. While 3G has a larger network coverage than Wi-Fi, it is known to have a larger energy consumption when sending and receiving data [7]. Typically, a Wi-Fi AP has a network coverage of around 200m, and has about twice the energy consumption when transmitting data compared to 3G [8].

Accordingly, in this paper, a peer management policy designed to increase the stability and efficiency of the entire P2P network is suggested by taking into account the characteristics of the currently connected network and factors related to energy consumption.

2. Related Work

2.1 P2P Overlay Multicast Tree

The P2P overlay multicast network scheme has been suggested as a way of providing stable multimedia streaming services [9]. With this scheme, during the construction of the P2P tree, joining and leaving of peers are quantified by taking into account their level of stability which is represented by trust values that are calculated, and the tree is constructed using peers with high trust levels. Figure 1 shows the configuration of the typical P2P overlay multicast tree network.

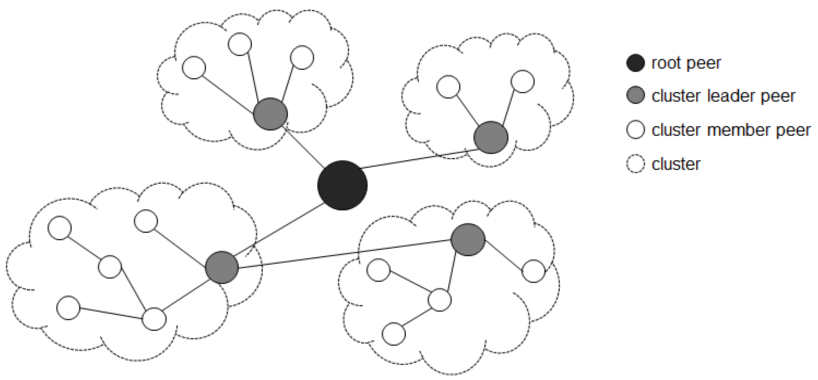

Figure 1. Typical Configuration of a P2P Overlay Multicast Tree Network

2.2 Proactive and Reactive Methods

2.2.1 Proactive Method: With the proactive method, the path selection information for data transmission is established in advance by the system. While this method has the advantage that the path information can be immediately provided when needed, it has the shortcoming that the path information has to be renewed when the path has to be changed with the movements of nodes.This method requires a lot of energy consumption as the network topology changes because the already established routing information has to be renewed and rerouting has to take place. A major protocol that uses this method is DSDV(Destination Sequenced Distance Vector)[10].

2.2.2 Reactive Method: With the reactive method, routing information is constructed every time it is needed for data transmission. In other words, new routing information is constructed each time regardless of the path changes with the movements of nodes. Accordingly, it has the advantage that routing information can be immediately used even when the routing is changed. However, it has the shortcoming that routing information has to be renewed every time there is a change. With this method, energy consumption is related to the data transmission rate.That is, because re-routing takes place every time data transmission occurs, in a network with a high data transmission rate, there will be large energy consumption. But if it is the opposite case, and the number of data transmissions is low, there will be low energy consumption for performing routing. One of the major protocols using this method is the AODV (Ad hoc On-demand Distance Vector) protocol[11].

2.2.3 Hybrid Method: With the hybrid method, routing is done not using a single method but multiple routing methods are used to perform the routing according to the specific situation. For example, ZRP (Zone Routing Protocol) uses a combination of proactive and reactive methods and forms a zone for each node.A zone includes nodes that are close, as determined by the number of hops specified in advance. The nodes within a given zone manage routing information using a proactive method, and the nodes outside of it manage routing information using a reactive method[12]. Also, PAR (Power Aware Routing) is a scheme in which routing is performed according to the amount of energy of each node, and it prevents the need for having to reconfigure the topology when a specific node runs out of battery[13]. It guarantees the time that the entire network can keep up the connection.

2.3 Network Configuration Algorithms That Take into Account Energy Consumption

2.3.1 MTPR (Minimum Total Transmission Power Routing): MTPR is a protocol that simply tries to minimize the energy consumption for sending packets without consideration of the remaining battery life. Given a routing path R = n0, n1, ... , n_k, n_0 is the source node and n_k is the destination node. The total transmission energy needed for setting up the path can be found using the following formula.

$$P_l = \sum P(n_i,\ n_{i+1}) \tag{1}$$

Note that $p(n_i, n_j)$ is the function that gives the energy needed for the transmission period between hops. The optimal routing path for l_0 is as follows.

$$P(l_0) = \min_{r_j \in r*} P(r_j) \tag{2}$$

Here, r represents a set of all possible paths. The energy needed to accurately send a packet is proportional to the distance[14]. Under MTPR, among the set of paths, the one with the minimum P_l is chosen as the path.But as the path with the shortest routing path and the largest number of hops is chosen, the packet transmission time is increased. Therefore, sufficient energy for nodes to set up a network and provide a stable service can't be guaranteed. Also, MTPR has the following shortcoming: given that the energy needed for transmitting packets is constant, it will become the same as an existing routing protocol that performs routing based on the minimum number of hops.

2.3.2. MMBCR (Min-Max Battery Cost Routing): In MMBCR, nodes with the lowest remaining battery life are compared for each path and the one with the greatest amount left is chosen. For example, given some path j, R_j refers to the node with the least amount of battery in the path with respect to battery B_i.

$$R_j = \min_{i \in router_j} P(r_j) \tag{3}$$

Under this type of a routing method, because the nodes with low amounts of battery life are not used to form the routing path, the life of the overall network will be increased. However, in contrast to MTPR, transmission times will increase, and energy consumption won't be minimized.

2.4. Other Work

S.Miyake and M.Bandai [15] suggested mobile P2P which improves energy efficiency using situational information of users. This paper suggests a scheme that allows the mobile device itself to decide whether to wakeup or sleep based on a server-based model and a client-based model.Also, the P2P structure was conceptualized into a two-stage structure consisting of super-peer and sub-peer by making it into two layers[16]. The suggested two-layer scheme is as follows.

◦MIS (Maximal Independent Set) system: Random numbers are assigned to distributed peers and the number of each peer is compared with the number of an adjacent node, and the one with the greater number becomes the super-peer.

◦Energy-Greedy System: Similar to MIS, except that the numbers are not random but represent the amount of battery currently remaining at peers.

In addition, a scheme was suggested in which, when the energy of the super-peer is exhausted, it is replaced with a new super-peer, as well as a study that changes the routing path accordingly.

3. A P2P Peer Management Scheme for Energy Efficiency

3.1. Basic Concepts

Previous studies have not taken into account multiple wireless interfaces and mobility of mobile devices. As mentioned in the introduction, many different types of mobile networks are available today, including 3G, 4G, Wi-Fi, and Bluetooth.Therefore, mobile devices, which have limited energy capacities, have to construct the P2P environment according to the specific characteristics of the network that they're connected to in order to improve energy efficiency. In addition, because mobility of mobile devices is related to their battery consumption, this fact has to be taken into account as well with respect to overall energy efficiency.In mobile P2P environment, because of the mobility of the mobile device, it will connect to many different types of networks. Therefore, when the device is idling, a communication module with the lowest stand-by energy consumption will be used during the communication stand-by state, and when P2P data transmission gets underway, the device will switch its connection to a network with a high transmission efficiency, taking into account the download size and the speed of the network, in order to increase the overall energy efficiency.

3.2. Suggested Scheme

3.2.1. When Not Taking into Account Mobility: Key information needed to download streaming data on mobile P2P include the download size, current battery level, and transmission speed of the network (the speed realistically achievable according to the congestion in the area and other various types of interferences, and not a theoretical speed).Generally, the energy-greedy approach of node selection is inefficient, in which a node with a large battery level remaining is simply selected. Currently, sub nodes connect to networks with differing transmission speeds. Therefore, going forward, it would be much more efficient to choose a parent node with an appropriate amount of battery life by taking into account the size of the download.

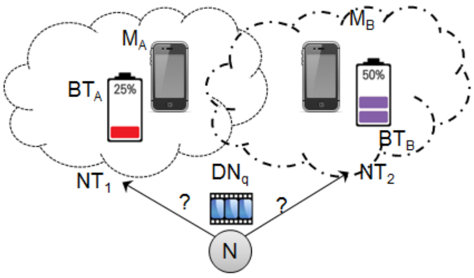

Figure 2. State of the Network

In Figure 2, the expected download time of the streaming data is given by Formula 4. In addition, Formula 5 is used to find candidate nodes with appropriate battery life, and Formula 6 is used to choose the device to use in the end.

$$\text{estimated\_dn\_time} = DN_q \,/\, (NT_k * 8\text{bit}) \tag{4}$$

$$\text{candidate\_nodes} \in BA(\text{estimated\_dn\_time}) + BA(\text{estimated\_dn\_time})*15\% \,\} \tag{5}$$

$$\text{select\_node} = \text{choose of MAX} \{ \text{candidate\_nodes} \} \tag{6}$$

Note that in Formula 5, because it may be the case that downloading is not the sole thing the mobile device is doing, an additional 15% is applied to the battery capacity needed for the download.As shown in Figure 3, a typical greedy system chooses M_B as the child node, which relatively has a lot of battery life, regardless of the amount of DN_q. In a multiple network situation, however, network characteristics need to be taken into account. For example, given that DN_q = dMByte, download speed of NT1 = aMbps, and NT2 = bMbps, the download speed of Network 1 will be (8×d/a) seconds, and the download speed of Network 2 will be (8×d/b) seconds.But suppose that the device that's connected to Network 2 is chosen as the peer simply by checking its remaining battery life. If a slow network with a lot of battery life is chosen, sufficient battery life needs to be secured. As shown in Figure 3, the remaining battery life of the device connected to Network 2 is at 50%. If there is insufficient battery life remaining to download DN_q, in order to finish downloading the remaining data, the tree structure needs to be reconfigured (moving of sub trees), which involves additional battery consumption.

Algorithm1 : No_Mobility()

Parent node selection method(size of the current battery & remaining size of streaming_file, does not consider the mobility)

Begin

while(count_candidate_nodes) {

Time_down_i = DN_q / NT_i × 8bit;   // estimated download time

---

Candidate_Battery[ ] = { Time_down_i ∈ { BA_k + (BA_k× 15%) } };
if (Candidate_Battery[ ] == empty) then
waiting; // *We have to wait until the new entry node with the capacity to meet.*
Candidate_nodes ∈ { MAX of Candidate_Battery[ ] };
// *We will select the node with the most adequate battery for download.*
}

3.2.2. When Taking into Account Mobility: In this section, the mobile devices are on the move, and the conditions are as follows.Key information needed to download streaming data on mobile P2P is as follows.

∘Download size: DN_q

∘Movement speed of the device in meters per second: SPD_k (m/sec)

∘Energy consumption rate per second according to movement speed (%/sec): EDP_k, exponential function ($y = a^x$) assumed

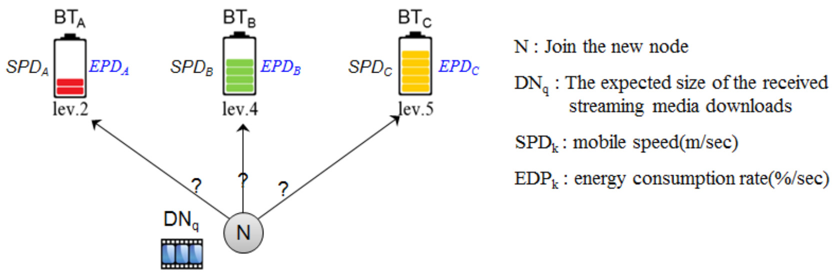

Figure 3. State of the Network

Even if connecting to a single network, simply choosing a node based on the remaining battery level is problematic. Given SPD_A = 0m/sec (immobile), SPD_B = 1.2m/sec, and SPD_C = 25.0m/sec, battery consumption rates according to the movement speed need to be taken into account. In other words, by choosing a node that has a small battery capacity, slow movement speed, and which can sufficiently handle the download, the problem of reconfiguring the topology can be overcome, and the overall energy consumption can be reduced as well.When considering mobility in a multiple wireless networks environment, first an assumption is made that the mobile device is immobile, and a group of candidate nodes that have enough battery life to complete the download is determined. Next, among these candidate nodes, one that has a slow movement speed and also have sufficient battery life is chosen as the final node.

Algorithm2 : Mobility()//*Candidate nodes are calculated from the algorithm 1.*
Begin
while(count_candidate_nodes) {
EDP[] = Compute_EC(SPD_k); //*Calculating the energy consumption of each node*
MBT_k[] ⊂ EDP[]* Time_down_i; //*Calculating the amount of battery of the mobile&*
//*Select nodes of the amount of the appropriate battery*
if (MBT_k[] == empty) then
waiting; // *We have to wait until the new entry node with the capacity to meet.*
Candidate_nodes ∈ { MIN of MBT_k(Candidate_nodes_speed[ ]) };
}

4. Performance Evaluation of the Proposed Model

4.1 Experimental Environment

In this section, the suggested scheme was simulated in an experiment. Also, using the results obtained, its performance was compared with that of a network using a proactive routing method, and a network using a reactive routing method.Table 1 lists the variables related to the experimental environment.Also, in order to measure the time the network is kept up, some particular amount of energy (a random value) is allocated during peer generation (note that the lowest possible amount of energy is limited to 20% of the total energy). Once one or more peers among the 200 peers have consumed the entire energy available, the test ends.

Table 1. The Experimental Environment

Variable	Value	Variable	Value
Number of peers	100 per network	Energy consumption (for sending)	0.2% per min
Communication coverage	100m x 100m	Energy consumption (for receiving)	0.1% per min
Video bandwidth	SD(4Mbps)	Node movement speed	0 ~ 20(m/sec)
Speed of network A	10.0Mbps	Speed of network B	1.0Mbps

Network A = Real-life speed of LTE-A / Network B = Real-life speed of 3G

4.2 Experimental Result

Looking at the experimental results shown in Figure 4, because the random approach takes no account of the state of the battery level of candidate nodes but makes the selection randomly, there is a great tendency of the nodes' battery level falling below the minimum (10%), resulting in an extremely short average keep-up time of the network.With the energy-greedy method, because the node with the greatest battery level is chosen as the super node in the initial node selection, the network lifetime is longer. But the suggested method has the longest network lifetime, for it takes into account the download size and the transmission speed, and compared to the energy-greedy method, the improvement can be as much as 14.32% as the number of nodes increases.Figure 5 shows the total battery consumption amount when the number of mobile nodes is 100. For changes according to the data transmission rates, it can be seen that there is little change for the proactive routing method but for the proposed method, the energy consumption is lower as the transmission rate is reduced. Figure 6 shows the number of packets received by the receiving node. The results were compared with the performance of AODV, which uses a reactive method, and ZRP, which uses a hybrid method. Looking at the results, it can be seen the existing methods which do not take into account energy consumption show rapidly degrading performance with increasing time as the nodes that deliver packets between paths leave the network. In contrast, the suggested algorithm shows an overall stable performance and is able to process a large amount of data.Figure 6 shows the number of packets received by the receiving node. The results were compared with the performance of AODV, which uses a reactive method, and ZRP, which uses a hybrid method. Looking at the results, it can be seen the existing methods which do not take into account energy consumption show rapidly degrading performance with increasing time as the nodes that deliver packets between paths leave the network. In contrast, the suggested algorithm shows an overall stable performance and is able to process a large amount of data.

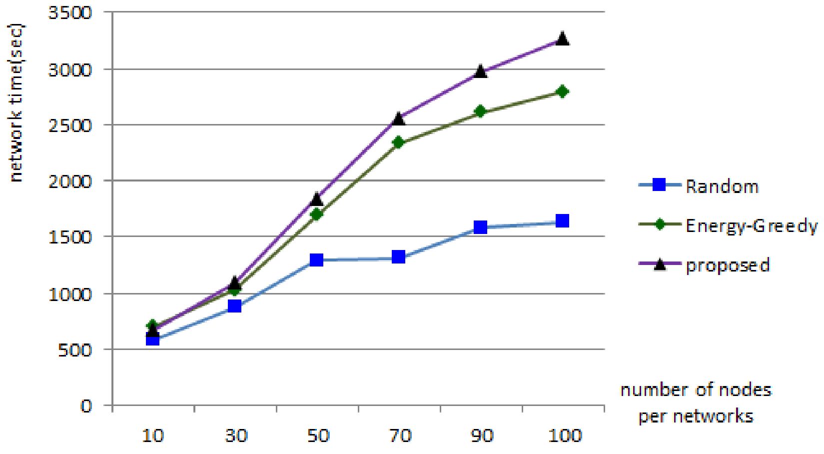

Figure 4. Average Network Lifetimes

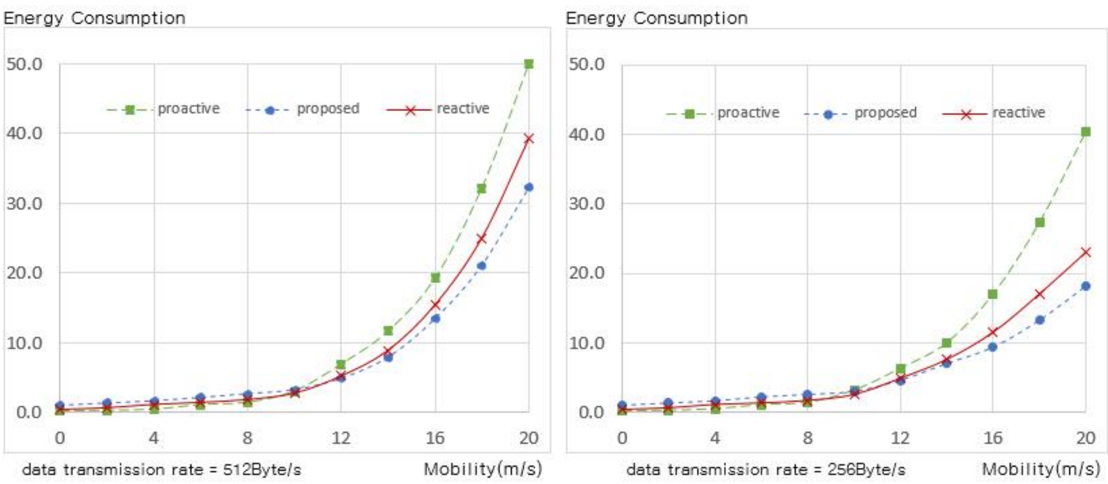

Figure 5. Energy Consumption (Number of Nodes = 100)

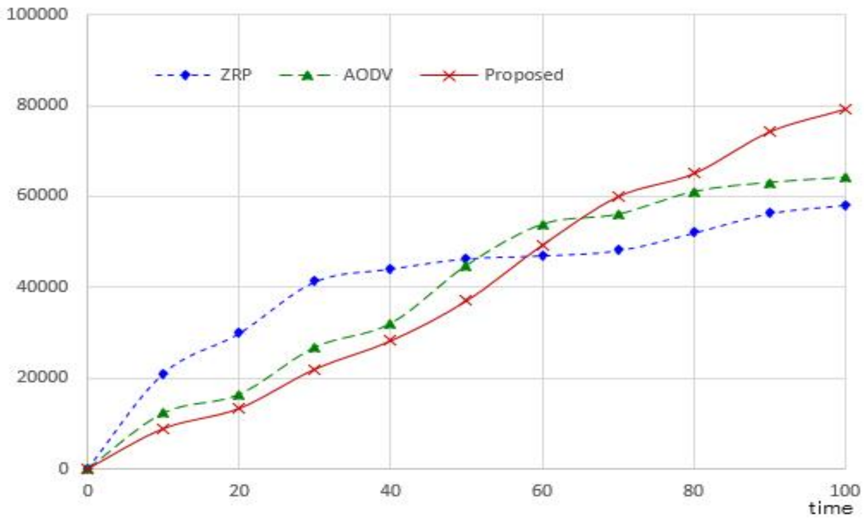

Figure 6. The Number of Packets at the Receiver Node

5. Conclusion

In an environment where the mobile devices are able to set up an overlay network using globally wired networks such as 3G and LTE as well as using local wireless networks such as Bluetooth and Wi-Fi Direct, mobile P2P systems are garnering attention as key technology for the streaming service sector, including video conferencing and VOD.Due to the limitations of mobile devices, however, problems may occur with the stability of the system. The small and limited capacity of the battery of mobile devices, especially, is one of the important factors when it comes to the stability of a mobile P2P system. Also, mobile nodes switch the network they're currently connected to on a constant basis for the reason that they're mobile. Therefore, the transmission speed of the network to which a mobile device has connected and the remaining data left to be downloaded have to be taken into account when setting up a mobile P2P system. In this paper, a peer management scheme was suggested which takes into account energy levels and network conditions, for setting up a stable and efficient mobile P2P network in an overlay multicast environment. The suggested scheme not only takes into account battery capacities but also calculates the size of the streaming data to be downloaded, so that a stable service can be provided.For future work, a study that takes into account the characteristics of many different types of networks will be done, as well a study on recovering from errors in order for increased network stability.

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