A Study on Materials and Development of Wireless Mobile Communication

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Abstract. In modern society, the need for rapid information exchange is increased continuously. As a result, the telecom industry has grown rapidly to more than double size of the global automotive market and has a major impact on the global economy. With the rapid development of the wireless communication market, a new concept of semiconductor materials having better physical and electrical characteristics. In this paper, we study on relationship between material engineering and wireless communication system. We introduce a greedy heuristic algorithm which optimize the wireless network construction for mobile streaming systems.

1. Introduction

The development of the mobile communications semiconductor industry is based on new semiconductor materials and semiconductor implementation process technology. Currently, a power amplifier using gallium arsenide is embedded inside the mobile phone terminal [1]. Device studies using gallium nitride and silicon carbide are underway to realize power amplifiers for base stations that require greater power amplification than mobile handsets and mobile communications semiconductor components that operate normally under conditions of high temperature and high pressure.

Semiconductor materials play an important role in manufacturing wireless terminals. Production of all semiconductor components such as DRAM and power amplifiers begins with semiconductor single crystal growth. Currently the most widely used semiconductor material is silicon (Si). When silicon oxide (SiO₂), which is also the main component of sand, is reacted with carbon at high temperature, polycrystalline silicon having 95-97% purity can be obtained. Further, after a finer refining process, polycrystalline silicon having a purity of 99.99% or more is obtained. Polycrystalline silicon is made up of numerous fine crystals. At the interface between the crystals, the atoms are not regularly arranged. This causes the movement of electrons in the semiconductor. Therefore, in order to be used as a semiconductor device material, a monocrystalline silicon having no interface is required.

The polycrystalline semiconductor is immersed in a crucible having a high melting point such as graphite or quartz, and then is heated to a temperature of more than the melting point of the semiconductor to form a liquid state [2]. When the seed crystal is immersed in liquid phase and then slowly pulled up, single crystals grow between the liquid phase and the seed crystal to form a single
crystal semiconductor. When the cylindrical surface of the cylindrical single crystal thus formed is ground and made uniform, a flat surface for indicating the direction is formed, and then cut to a thickness of 0.5-0.7 mm using a diamond saw, a semiconductor wafer is produced.

However, such a semiconductor wafer is not directly used for device fabrication. Instead, it is used as a substrate to make a more precisely controlled semiconductor thin film. This is called epitaxy growth. There are physical and chemical methods for epitaxial growth. The physical method is to charge the semiconductor constituent material into an ultrahigh vacuum reactor of 1*10^{-10}torr or less, and then heat the crucible containing the semiconductor material so that the vaporized semiconductor atoms reach the substrate to form crystals. The chemical method refers to the growth of a crystal thin film layer by causing a gas containing a semiconductor constituent substance to cause a chemical reaction at a high temperature wafer surface. The semiconductor thin film grown by the epitaxial method has perfect crystallinity.

There has been much work on material and wireless streaming systems in the literature [3-7]. Based on the overlay topology construction, these peer-to-peer streaming systems can be categorized into two types: tree-based and mesh-based. Tree-based peer-to-peer streaming systems build one or more trees rooted at the server. The media content flows from the server to the peers along the trees. Multiple trees are employed to make use of the uplink bandwidth of the leaf peers. Mesh-based peer-to-peer streaming systems build a loosely connected mesh where each peer establishes connection with several neighbours. Peers exchange the availability information of the media content with their neighbours and help each other to deliver the media content. Most of the works take little or no consideration of huge diversity of the link bandwidth of peers.

With the rapid expansion of the Internet, more and more individual computers are connected to the Internet which becomes potential peers for wireless streaming systems [8, 9]. Diverse and limited peer access link bandwidth is an important characteristic when these individual computers join a peer-to-peer streaming system. First, as different peers have different download bandwidths, it is desirable that peers with higher download bandwidth receive the media content at a higher bit rate while peers with lower download bandwidth receive the media content at a lower bit rate. This is achievable through the media streaming encoding technology (e.g., Multiple Description coding (MDC) and layered encoding). Besides, the overlay topology should guarantee a path from the source to the peer with sufficient bandwidth. Second, the limited uplink bandwidth should be utilized wisely so that the total downloading rate is maximized. In this paper, we propose a new scheme to optimize the overlay topology construction for peer-to-peer streaming systems with heterogeneous downloading requirements. Although the scheme is designed for wireless peer-to-peer media streaming systems, the result can also be applied to peer-to-peer content delivery or file downloading systems.

2. Overview of Proposed Communication System

Due to the NP hardness of the MDR problem, as a starting point, in this section we propose a greedy heuristic algorithm to find the maximum number of edge disjoint trees given the network topology \( G \). It is a centralized algorithm which requires the complete information on the peers and their access link bandwidth. As we know, in practice, this information is dynamic and usually cannot be obtained in advance. We will further propose a distributed algorithm to handle the dynamics of peers in the next section. Nonetheless, the centralized heuristic algorithm serves as the foundation for the distributed algorithm and the benchmark when we evaluate the performance of the distributed algorithm in performance evaluation section.

The basic idea of the greedy heuristic algorithm is to pick out a maximum edge disjoint tree from graph \( G \) one by one until there is no such a tree. Before we apply the algorithm to graph \( G \), we need to modify the graph by replacing each link of bandwidth \( b \) with \( b \) parallel links each of which has bandwidth 1. This modification will not change the result of the algorithm. Therefore, each tree represents a sub-stream with bit rate of 1. The receiving bit rate of a peer is equal to the number of trees the peer is on. Each tree must be rooted at the source node. To ensure the server transmits as many sub-streams as possible, the number of children of the root is limited to one for each tree. Two factors are taken into consideration for the tree construction. First, the height of the tree should be minimized. The
height of the tree determines the delay between the source and the peer. To minimize the height of the tree, we should push the peers with higher uplink bandwidths to the source node as close as possible. Second, fairness bandwidth allocation between different trees should be maximized. When a peer receives the media content from several different trees, the delays to the source along the trees may be different. The final end-to-end delay from the source to the peer is determined by the worst case, i.e. the longest delay among all the delays. One way to minimize the difference among these delays is to minimize the difference of the tree heights, as the height of the tree represents the longest end-to-end delay approximately. Fairness here means that the uplink bandwidth should be shared among different trees in a fair manner. As a result, the height difference among different trees is minimized.

The fairness is realized by a property of the peer called fanout. Fanout is a value which is used to evaluate the forwarding ability of a peer. The fanout of a peer is equal to (uplink bandwidth)/(downlink bandwidth). The larger the fanout, the more children the peer can have. We use fanout as the upper bound on the number of children a peer can have in one tree. The reason is two folds. On one hand, if the number of children is smaller than the fanout, some uplink bandwidth will be wasted definitely even if the downlink bandwidth is filled up with the sub-streams. On the other hand, if the number of children is more than the fanout for one tree, it means that the number of children is less than the fanout for another tree. This imbalance of uplink bandwidth allocation contradicts the fairness principle.

3. Distributed Algorithm
The greedy heuristic algorithm works well if the information of the peers and their access link bandwidths are given in advance. However, in practice, peers join or leave the peer-to-peer system frequently which is known as churn. Due to the frequent churn rate, it is impossible for the server to run the greedy heuristic algorithm every time when there is a peer joining or leaving. When a new peer joins the system, it should be grafted to the system in an efficient and distributed fashion. The topology mismatch is another issue when we design a practical peer-to-peer streaming system. A practical peer-to-peer streaming system should be able to adapt itself to the changing overlay topology by alleviating the mismatch. As we mentioned before, peers join and leave the system in a random manner. According to the join procedure, a new peer is always a descendant of the existing peers after it joins the system. As a consequence, the overlay topology is changing as the peers join and leave and is dependent on the order of the peers joining and leaving. Due to the randomness of the order of peer joining and leaving, the overlay topology may be far from the one constructed by the greedy heuristic algorithm. We propose a topology adjustment procedure to help the peer-to-peer system handle the dynamic peer joining and leaving.

The intuition behind the adjustment procedure is to locate the peers whose positions do not match their level values and move these peers to a proper position. It is composed of three steps. (1) Step 1. The peer (We use v to denote the peer in the rest of this section) sends a REQUEST message upstream along the tree towards the root. The REQUEST message includes the value of level of v and a hop counter. Each peer receiving the REQUEST message will forward it to its parent and add 1 to the hop counter. The REQUEST message will stop when it reaches the root. (2) Step 2. Each peer receiving the REQUEST will compare the value of level in the message with its own value of level. If its own level is less than that in the message, it will send a GRANT message back to v. The GRANT message contains its own value of level, its parent, the residual uplink bandwidth of its parent and the value of the hop counter. (3) Step 3. If v does not receive any GRANT message, it does nothing. If v receives one or more GRANT messages, it will choose one peer to be its new parent based on the following rules: sort the peers in a descending order of their hop counts; select the first peer whose parent has non-zero residual uplink bandwidth and take its parent as the new parent of v. The peer v and the subtree rooted at v will become a subtree of the new parent. If there is no such a peer whose parent has non-zero residual uplink bandwidth, the peer checks itself to see if there is any residual uplink bandwidth. If no, the peer does nothing. If yes, the peer v will select the peer with the largest hop count and take its parent as the new parent. As there is no residual uplink bandwidth of the parent, one child of the parent will be replaced by v. The old child will become a child of v. The rationale behind the rules is to move the peer as close to the
root as possible while minimizing the disturbance to the existing tree structure. Figure 1 shows the details of system model for material-based wireless data streaming.

4. Performance Evaluation

In this section, we study the performance of the proposed algorithms through simulations. We have implemented the proposed scheme in NS-3. Peers are selected randomly from the stub networks and the bandwidth of the links in the transit network is set to be sufficiently high (1000 Mbps in the simulations). We compare our scheme with the Mitchell, Dem’yanov and Malozemov (MDM) algorithm as it is the closest work to ours in the sense that both of the algorithms try to optimize the overlay topology for peer-to-peer media streaming systems. The main difference is that our scheme considers heterogeneous downloading rates while MDM assumes a uniform downloading rate. The simulation adopts three performance metrics such as satisfaction, end-to-end delay, and link stress.

We first compare the average satisfaction of peers under different sizes of the peer-to-peer streaming system. We use the number of peers in the system to represent the size of the system. Figure 2(a) shows the average satisfaction as we change the system size. We can observe that the greedy heuristic algorithm demonstrates the best satisfaction and the distributed algorithm outperforms MDM by about 30% on the average. It suggests that our scheme can make more efficient use of the uplink bandwidth of peers than MDM. With the increase of the system size, the average satisfaction drops for all the three schemes.

Figure 2. Network simulation results: (a) ratio average satisfaction; (b) average end-to-end delay.

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**Figure 1.** Basic system model of material-based wireless data streaming.
The end-to-end delay is an important performance metric for peer-to-peer media streaming systems. As we can see later, sometimes end-to-end delay and satisfaction are two conflicting performance metrics and the best solution is a trade-off between these two metrics. Figure 2(b) shows the end-to-end delay under different system sizes. We can see that with the increase of the system size, the end-to-end delay increases as well due to the large tree heights. When the system size is small, the greedy heuristic algorithm achieves the shortest end-to-end delay. As the system size becomes large, the end-to-end delay of MDM is shorter than that of other two schemes. The reason is that MDM is a scheme focused on minimizing the end-to-end delay. The advantage of MDM is more obvious when the system size is large.

5. Conclusion
The Fourth Industrial Revolution fuses previous technologies that led to the transformation of industrial infrastructures and creates new technologies. A world in which things, things, things and people are connected and communicated organically. The world is the center of all technology. The core of Next Generation is convergence between ICT technologies [10, 11]. As material engineering progresses, the foundation for the growth of IT technology has been established. We have a plan to combine new materials with 5G communication technology.

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