A Broadcast-VOD Protocol in an Integrated Wireless Mobile Network*

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Abstract

In this paper, we investigate a broadcast-VOD problem in an integrated wireless mobile network. Existing wireless mobile networks can be classified into single-hop (such as GSM system) and multi-hop mobile networks (such as Ad-hoc network). A single-hop wireless mobile network is characterized by each base station (or BS) connecting to other BS by a wired network, but each mobile host (or MH) communicating with its own BS within one-hop transmission radius. Our proposed wireless mobile network is an integration of single-hop and multi-hop mobile networks. The integrated network is characterized by each BS connecting to other BS by a wired network, but each MH communicating with a BS within multi-hop transmission steps. In our integrated network, BSs are connected by a 2-D tori interconnection network. In addition, an important application, called as broadcast-VOD protocol, is presented in such integrated network. Therefore, two contributions are presented in this paper: (a) a new integrated wireless mobile network is proposed, (b) a fast broadcast-VOD protocol is introduced in such new network. In our strategy, VOD-data are well scheduled and broadcasted among 2-D tori-BSs such that the average waiting time is minimum. In each cell area, a VOD (Video On-Demand) is dynamically requested by any MH at the different time to on-line construct a multicast tree, while the root node of multicast tree is a BS. This guarantees that each MH can receive the VOD-segment from its corresponding BS within minimal waiting time. Performance analysis verifies that our proposed scheme outperforms existing schemes.

Keywords: cellular infrastructure, broadcasting, mobile Ad-hoc network (MANET), mobile computing, multicast, wireless network.

1 Introduction

A video system is consisting of a video-server with a high capability of disk-array, a transport network (ATM or cable-modem), and the end user. Up to date, there are many VOD research results in the wired-network [1][6][9][11][17]. For instance, an optimal video placement strategy is proposed [9] in the high-speed ATM network. In addition, Su and Wang [21] proposed an on-demand multicast routing Scheme. Their scheme allows the destinations accessing the same multicast stream at different time by using a buffering technique to reduce the communication bandwidth.

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Existing research system are mainly based on either high-speed network (ATM, Ethernet) or cable-TV network [1] [6] [9][11][17]. The requisition for bandwidth and quality does not allow the efficient implementation of such demanding services as VOD over the wireless mobile network. It is observed that a wireless communication usually requires digital data to be protected against channel error, as the communication link tends to be less reliable than in a wired-network. However, recently, there are many VOD research results in the wireless network [8][16][23][26]. Initially, Meng [23] proposed a wireless video system with low-power consumption and high computation performance which is based on their proposed elegant compression algorithm. Recently, Xu *et al*. [26] have proposed a QoS-directed error control scheme of video multicast in the wireless network. Note that their scheme has high error recovery rate for the video frames and with excellent scalability. In addition, Zheng *et al*. [8] designed a QoS-aware mobile video communication strategy. This strategy utilizes a new video-frame compressed technique to satisfy the QoS requirements. More recently, Davies *et al*. [16] developed a supporting adaptive video applications in the mobile environment. As a conclusion, we observe that existing VOD-in-wireless researchers focused on how to build a QoS transmission in the wireless network.

This paper is motivated by developing a new mobile network model. In such new model, we investigate a fast broadcast-VOD problem in the new wireless network. Existing wireless mobile networks are classified into cellular network architecture (or single-hop wireless network with a fixed infrastructure, such as GSM system) and multi-hop wireless mobile networks (without a fixed infrastructure, such as Ad-hoc network). Mobile Ad-hoc networks (MANET) [10] [24] [7] [12] [15] [18] [3] consists of wireless hosts that communicate with each other, in the absence of a fixed infrastructure. A cellular network architecture with a fixed infrastructure is normally constituted by a set of base stations, while each base station communicates with a mobile host within a single-hop communication radius. A cellular network architecture is characterized by each base station connecting to other base station by means of the wired-network, but each mobile host communicates with its own base station within one-hop transmission radius. Due to considerations such as radio power limitations, power consumption, and channel utilization, a mobile host may not be able to communicate directly with other hosts in a single-hop fashion. A multi-hop scenario occurs, where the packets sent by the source host are retransmitted by several intermediate hosts before reaching the destination host. In MANET, host mobility can cause frequent unpredictable topology changes, thus design protocols more complicated than traditional single-hop wireless mobile network. Unfortunately, it is existing fewer applications in the multi-hop wireless network. Therefore, this paper is to present an integrated wireless network model, which is possessing natural advantage of both wireless networks. A related work is that Qiao *et al.* [20] proposed an integrated cellular and ad-hoc relay system. Qiao *et al.* [20] propose to integrate the cellular infrastructure with modern ad-hoc relaying technologies to achieve dynamic load balancing among different cells in a cost-effective way.

The major contribution of this paper is to propose an integrated wireless mobile network. Our integrated network is characterized by each base station connecting to other base station by a wired network, but each mobile host communicates with a BS within multi-hop transmission steps. Observe that, in our integrated network, BSs are connected by a 2-D tori interconnection network, which is called as the 2-D tori-BSs. One important advantage of our new network is to build a wireless network infrastructure by using less number of BSs. Our proposed scheme is suitable to build a wireless network infrastructure with low hardware cost. That is, there only needs fewer number of base stations in the same covering area, but each mobile host must communicate to a base station by the multi-hop fashion.

One important technique in single-hop wireless network is the video-on-demand problem, such that mobile user can retrieve video data through base station [17][11][9][1][6]. Some applications using the above technique is the distance learning and video conference, etc. In this paper, we will propose a fast broadcast-VOD scheme in our integrated network to handle the video-on-demand (VOD) problem. Therefore, two contributions are presented in this paper; (a) a new integrated wireless mobile network is proposed, (b) a fast broadcast-VOD protocol is introduced in such new network. In our strategy, VOD-data are well scheduled and broadcasting among 2-D tori-BSs such that the average waiting time is minimum. In each cell area, a VOD (Video On-Demand) is dynamically requested by any MH at the different time to on-line construct a multicast tree, while the root node of multicast tree is a BS. This guarantees that each MH can receive the VOD-segment from its corresponding BS within minimal waiting time. Performance analysis verifies that our proposed scheme outperforms existing schemes.

The rest of the paper is organized as follows. Section 2 introduces the new wireless network model. Our broadcast-VOD protocol is presented in Section 3. Section 4 illustrates performance analysis. Section 5 concludes this paper.

2 The Integrated Wireless Network Model

We now formally define our integrated wireless mobile network. Our integrated network is characterized by each BS connecting to other BS by a wired network, but each MH communicating with a BS within multi-hop transmission steps.

A wireless network can be formally represented as $G = (V,C)$, where V denotes the BS set and C specifies the wired-network connectivity. Each BS contains a separate router to handle its communication tasks. In this paper, we consider G as a 2-dimensional torus $T_{n_1 \times n_2}$ with $n_1 \times n_2$ BSs [25]. Each BS is denoted as $B_{i,j}$, $1 \leq i \leq n_1$, $1 \leq j \leq n_2$ and B_{i_1,i_2} has an edge connected $B_{(i_1 \pm 1) \bmod n_1, i_2}$ along dimension one and an edge to $B_{i_1,(i_2 \pm 1) \bmod n_2}$ along dimension two. Each edge is considered consisting of two directed communication links pointing in opposite directions. An example of $B_{i,j}$, $1 \leq i \leq 5$ and $1 \leq j \leq 5$, is given in Fig. 1. Each cell area is defined as a MH's moving area which bounds by four neighboring BSs as illustrated in Fig. 1, and each MH can connect to four neighboring BSs by the multi-hop fashion.

In our integrated network, BSs are connected by a 2-D tori interconnection network [25]. For simplicity, such structure is denoted as 2-D tori-BSs. We make the following observation. The main advantage of our integrated network is to reduce the number of BSs. Our integrated wireless mobile network is used to support a wireless network infrastructure using fewer number of BSs. The proposed broadcast-VOD protocol is divided into two parts.

1. **The Broadcast Protocol –** The original video data is partitioned into data subsegments, which are located on BSs, scheduled and broadcasting on the 2-D tori-BSs.

2. **The VOD Protocol –** Each MH performs the VOD protocol to receive the first data subsegment with minimal waiting time.

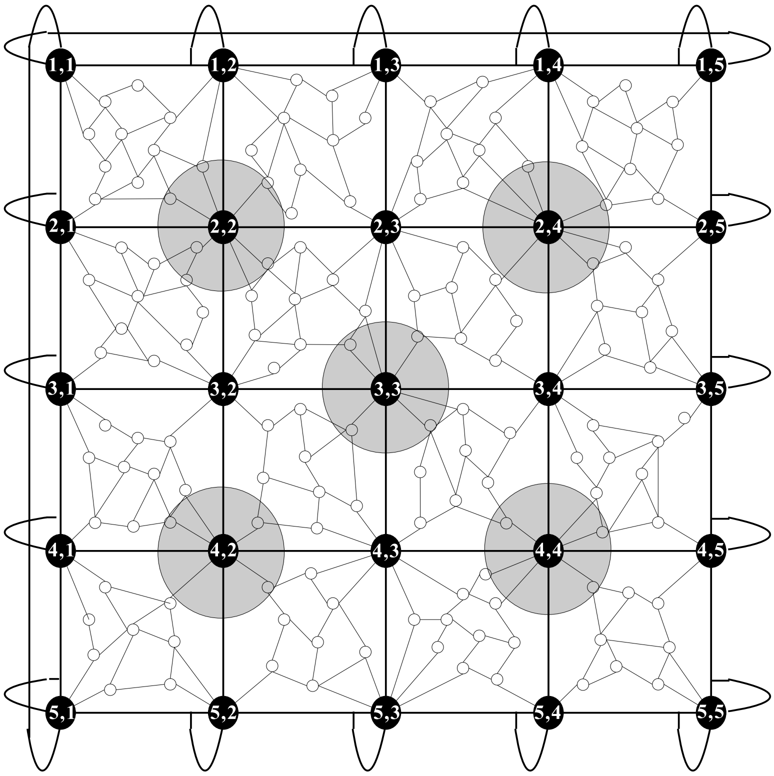

Figure 1: An example of $B_{i,j}$, where $1 \leq i \leq 5$ and $1 \leq j \leq 5$,.

3 The Proposed Broadcast Protocol

Two operations of broadcasting protocol in 2-D tori-BSs are introduced.

- **Data Assignment Operation –** It describes the data initialization of the video segments into the 2-D tori-BSs.
- **Data Broadcast Operation –** It denotes the data scheduling and broadcasting operations in the 2-D tori-BSs.

In the following, we will describe these operations in detail.

3.1 Data Assignment Operation

Consider that there is $n \times n$ 2-D tori-BSs. Given a video, denoted as S, which is divided into $2n^2$ data subsegments, so that S is equally split into $\{S_1, S_2, S_3, \ldots, S_{2n^2}\}$. It reflects the fact that each BS keeps two data subsegment at the same time. In other words, we assume that each BS just only keeps two data subsegments at any time. This indicates that our scheme has the advantage of low memory cost. An instance is shown in Fig. 2, if we assume that $n = 5$ and a video is divided into 50 data subsegments.

In the following, we will describe how to allocate the $\{S_1, S_2, S_3, \ldots, S_{2n^2}\}$ into $n \times n$ 2-D tori-BSs. We begin by classified the $\{S_1, S_2, S_3, \ldots, S_{2n^2}\}$ into two groups. First group, denoted as G_o, consists of odd number of data-subsegments $\{S_1, S_3, S_5, \ldots, S_{2n^2-1}\}$. Second group, denoted as G_e, consists of even number of data-subsegments $\{S_2, S_4, S_6, \ldots, S_{2n^2}\}$. Since the data allocation rule of G_o and G_e is similar, therefore, we mainly focus on describing

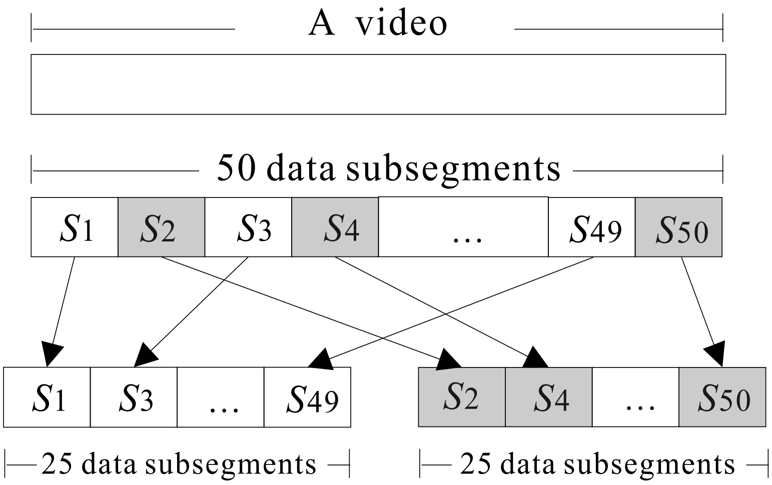

Figure 2: An example of video-partition scheme.

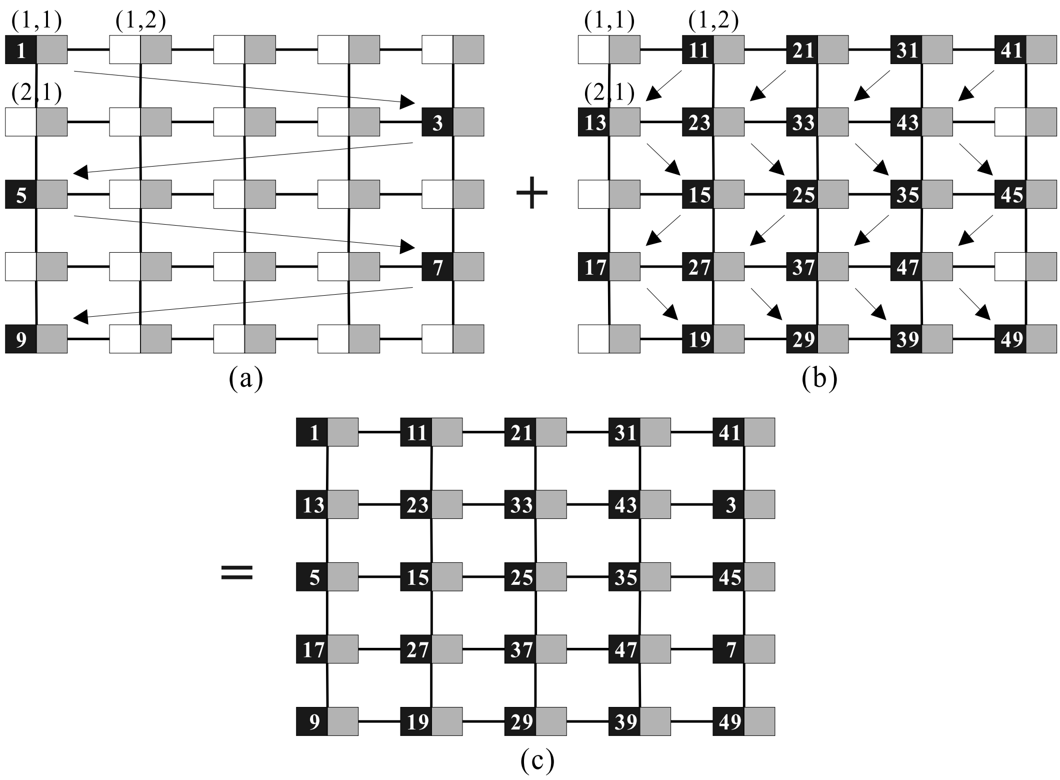

Figure 3: Data assigement of G_o.

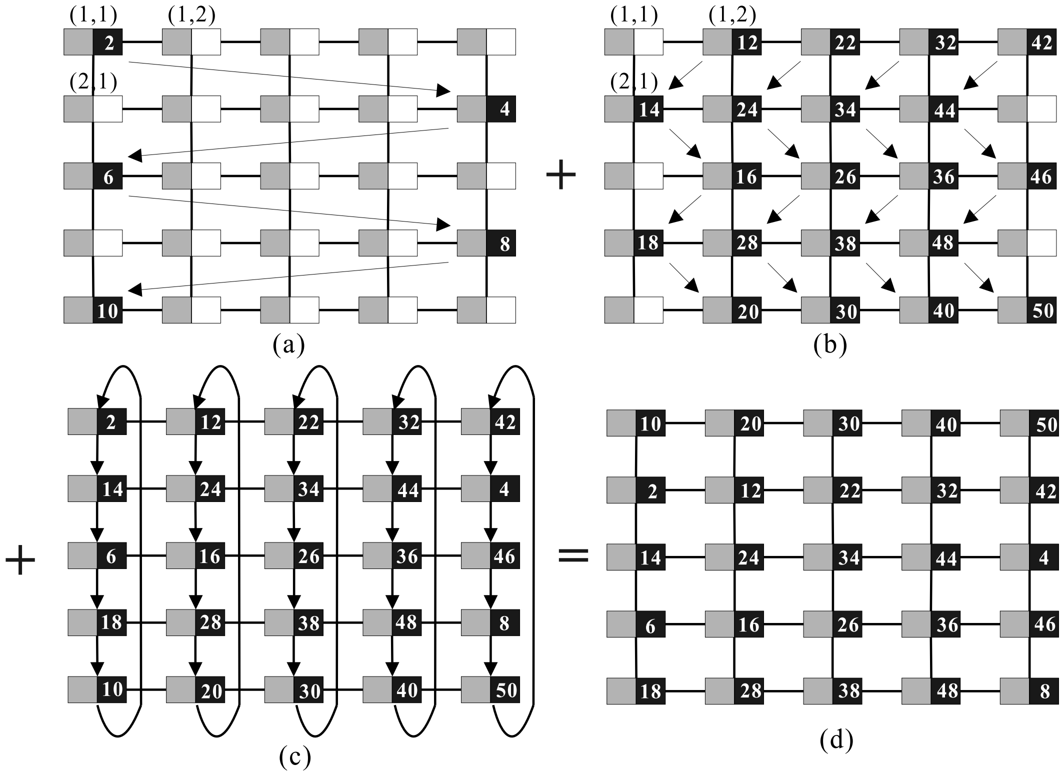

Figure 4: Data assigement of G_e.

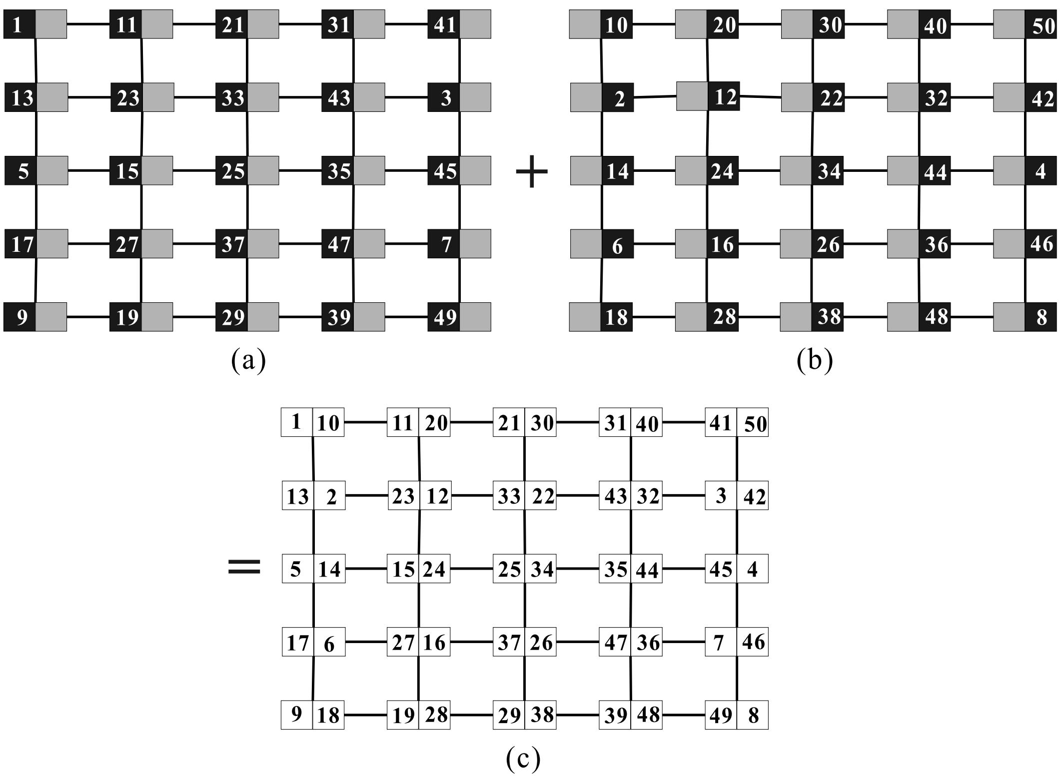

Figure 5: The combing result of G_o and G_e.

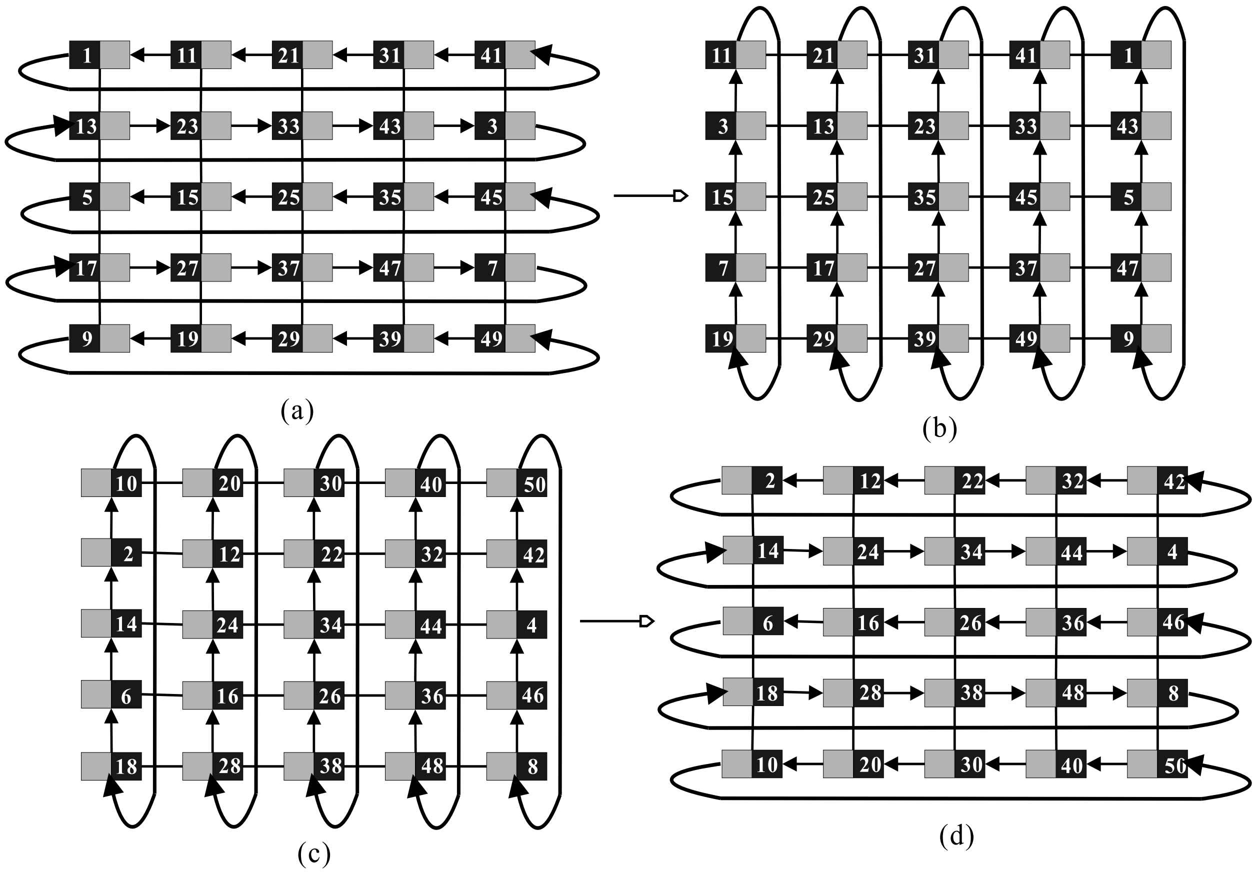

Figure 6: Examples of (a)(d) row-shift operations and (b)(c) column-shift operations.

the constructing rule of G_o. Recall above instance as illustrated in Fig. 2, a video with 50 data subsegments is split into $\{S_1, S_3, S_5, \ldots, S_{49}\}$ and $\{S_2, S_4, S_6, \ldots, S_{50}\}$.

Given $G_o = \{S_1, S_3, S_5, \ldots, S_{2n^2-1}\}$, G_o is again partitioned into two subgroups. The first subgroup, denoted as $G_o(1)$, where $G_o(1) = \{S_1, S_3, S_5, \ldots, S_{2n-1}\}$, and all of the remaindering data subsegments $\{S_{2n+1}, S_{2n+3}, S_{2n+5}, \ldots, S_{2n^2-1}\}$ are collected into second subgroup, which denoted as $G_o(2)$. The allocation of $G_o(1)$ and $G_o(2)$ into n^2 2-D tori-BSs is formally given below.

G1: Each element of $G_o(1) = \{S_1, S_3, S_5, \ldots, S_{2n-1}\}$ is sequentially put into $B_{1,1}$, $B_{2,n}$, $B_{3,1}$, $B_{4,n}, \ldots$, and $B_{n,1}$.

- For instance, consider a $B_{i,j}$, $1 \le i \le 5, 1 \le j \le 5$ as shown in Fig. 3(a), every element of $G_o(1) = \{S_1, S_3, S_5, S_7, S_9\}$ is put into $B_{1,1}$, $B_{2,4}$, $B_{3,1}$, $B_{4,4}$, and $B_{5,0}$ in order.

G2: Each element of $G_o(2) = \{S_{2n+1}, S_{2n+3}, S_{2n+5}, \ldots, S_{2n^2-1}\}$ is sequentially put into $B_{i=1,j}$, $B_{i+1,j-1}$, $B_{i+2,j}$, $B_{i+3,j-1}, \ldots$, and $B_{n,j}$, for $j = 2..n$.

- Recall above example as shown in Fig. 3(b), let each element of $G_o(2) = \{S_{11}, S_{13}, S_{15}, \ldots, S_{49}\}$, which are allocated into $B_{1,2}$, $B_{2,1}$, $B_{3,2}$, $B_{4,1}, B_{5,2}, B_{1,3}, B_{2,2}, B_{3,3}$, $B_{4,2}, B_{5,3}, \ldots$, and $B_{5,5}$. The final result is shown in Fig. 3(c).

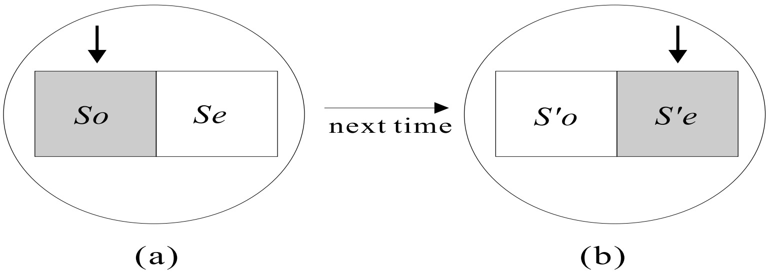

Figure 7: An example of data retrieving operation.

We now describe how to allocate $G_e = \{S_2, S_4, S_6, \ldots, S_{2n^2}\}$ into $n \times n$ BSs below. The partition of G_e into two subgroups is same with the work in G_o, and then we perform the same operation in G1 and G2 steps. An example is shown in Fig. 4(a) and Fig. 4(b). Observe that there is an additional operation is needed to be executed. In the n^2 2-D tori-BSs, each element in each column circularly shifts down one position. This operation is illustrated in Fig. 4(c). An assignment result of G_e is shown in Fig. 4(d).

As a result, combining with the positioning result of G_o and G_e, each BS keeps two distinct data subsegments. An example is given in Fig. 5.

3.2 Data Broadcast Operation

Before describing the data broadcast operation of G_o and G_e on n^2 2-D tori-BSs, we now define two kinds of parallel data shifting operations.

- **Row-Shift Operation –** For each row, a left-shift operation is performed in parallel if the row is an odd row. Otherwise, a right-shift operation is executed in parallel.
  - An example of the row-shift operations is illustrated in Fig. 6(a) and Fig. 6(d).
- **Column-Shift Operation –** A up-shift operation is performed in parallel for each column.
  - An instance of the column-shift operation is operated in Fig. 6(b) and Fig. 6(c).

We now introduce the data broadcast operation in the 2-D tori-BSs. The data broadcast operation is achieved by executing the data transmission of G_0 and G_e simultaneously.. The data transmission of G_o is achieved by repeatedly performing row-shift and column-shift operations. On the contrary, the data transmission of G_e is achieved by repeatedly performing column-shift and row-shift operations. A fully example is shown in Fig. 6 to express the data transmission operation of G_o and G_e. Based on the rule of our data assignment and transmission operations, each BS B has two data subsegments S_o and S_e at the same time, where $S_o \in G_o$ and $S_e \in G_e$. Assume that B will receive S'_o and S'_e from row-shift and column-shift operations, where $S'_o \in G_o$ and $S'_e \in G_e$. Two possible data retrieving operations are given below.

- If now is using S_o, then S'_e will be used on next time unit.

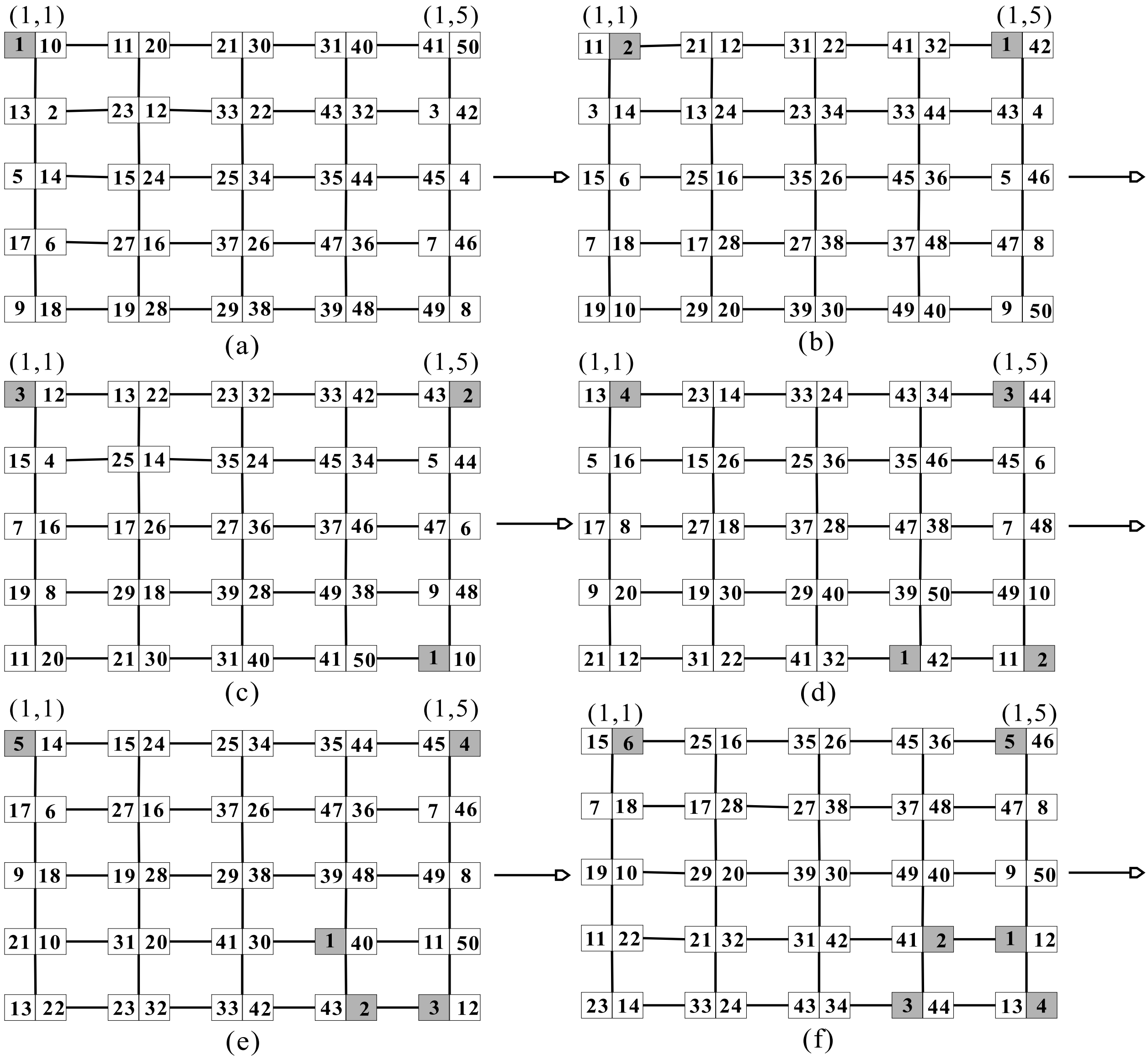

Figure 8: An example of data broadcast operation.

- If now is using S_e, then S'_o will be used on next time unit.

That is, in our data retrieving operation, these two data subsegments will be used interchangeably as displayed in Fig. 7. In addition, it is easily in Fig. 8 to see that S_1 is located in BS $B_{1,1}$ on time unit 1, S_2 is in $B_{1,1}$ on time unit 2, S_3 is in $B_{1,1}$ on time unit 3, etc. Other instance is illustrated in $B_{1,5}$, when S_1 is flowed to $B_{1,5}$ on time unit 2, and therefore $S_2, S_3, S_4, S_5, ..., S_{2n^2}$ will be sequentially flowed to $B_{1,5}$ on the forthcoming time units. Obviously, it is accomplished the data broadcasting operation.

4 The Proposed VOD Protocol

The VOD strategy is based on multi-hop transmission, which is divided into three operations.

- **The VOD Operation –** For each MH, a VOD operation is proposed to efficiently retrieve video data from BSs.
- **The Error-Handling and Handoff Operations –** Two possible cases are discussed for the failure transmission and handoff problems.

4.1 The VOD Operation

The VOD operation herein is equally to build a multicasting tree for multiple MHs since our scheme allows MHs request their VOD demand in the same cell area, and the broadcast protocol guarantees that first data subsegment will be coming to each BS after waiting a period of time. The design difficulty is that each MH's request time may be different. We now describe the construction of the VOD-multicast tree in same cell area with above consideration. Observe that each cell area can be seen as a MANET. Existing MANET multicast routing protocols [19] [4] [13] [5] [14] [22] [2] can be directly used in our scheme. Existing multicast protocols are classified into proactive/off-line [19][22] and reactive/on-demand [4][13][5][14] approaches. Proactive multicast protocol is to pre-build a shared-tree, and reactive multicast protocol is to construct a tree on-demand. Generally speaking, proactive multicast protocol takes high transmitting time since this approach needs high maintenance cost. The drawback of proactive protocol is not always finding the shortest-path. Therefore, proactive multicast protocol is not very suitable to the topology-changeability network. Two cases of our constructed VOD-multicast tree are discussed.

- **New Call –** Existing reactive/on-demand multicast protocols [4][13][5][14] are used for each new call of a MH to connect to a determined BS (the determined rule is explained later), such that the waiting time is minimal.
- **Joining to a Multicast Tree –** Existing proactive/off-line multicast protocols [19][22] are utilized to connect to a determined BS. A shared-tree is to be pre-builded, which all of the destination nodes of the multicast tree are waiting for first data-segment. Observe that the root of such shared multicast-tree is determined by a determined rule which is explained later. When a MH initiates a VOD request, a join operation is performed to join the shared-tree such that all of the destination node of the original tree and the new member are waiting for the same data-subsegment coming.

In the following, we present the determined rule, which is the rule of determining MH connecting to a BS with minimal waiting time of the first coming data subsegment. Four possible BSs may be connected. For simplicity, let LU, LD, RU, and RD respectively denote as left-up, left-down, right-up, and right-down BSs, as shown in Fig. 9. Each of LU, LD, RU, and RD should record the current stored two data subsegments, which is denoted as $X[i, j]$, where $X \in \{LU, LD, RU, RD\}$, $i \in G_o$ and $j \in G_e$. For a BS, suppose that $X[i, j]$ represents the two data subsegments, it is worth mentioned that if let $X[i', j']$ denote the two new data subsegments which received by performing a row-shift and column-shift operations, so that $i' = (j+1) \bmod 2n^2$ and $j' = (i+1) \bmod 2n^2$. For instance, consider $B_{1,1}[1, 10]$ as shown in Fig. 8(a), such that $B_{1,1}[11, 2]$ as illustrated in Fig. 8(b) at the next time unit.

One important work of the data-broadcasting scheme is to search a feasible path from a MH, which initiates a VOD request, to a BS B, where $B \in \{LU, LD, RU, RD\}$. The BS B satisfies the following condition; B is with maximum value i or j of $X[i, j]$, and $X \in \{LU, LD, RU, RD\}$. Suppose that $LU[15, 8], LD[11, 16], RU[3, 14]$, and $RD[17, 4]$ if $n = 3$ as shown in Fig. 9. We observe that the maximum value is 17, so a MH should flood a path-search packet to search a path to RD.

Following above description, we assume that the maximum value is M, while RD keeps value M. We observe that any new MH, which initiates a new VOD request, should connect to RD preserving at least $2n^2 - M$ time units. It is because that LU, LD, and RU will not get larger value than RD for $2n^2 - M$ time units. Reminder that each bast station just only keeps the current stored data-subsegment information. Following above example, BSs LU, LD, RU, and RD just knows $[15, 8]$, $[11, 16]$, $[3, 14]$, and $[17, 4]$, respectively. It implies that if any MH communicate to one of their four neighboring bast stations, then this MH just can acquire the information of one of BSs. However, each MH should know the data-subsegment information of all neighboring BSs. We will provide a formula such that if we can know one of data-subsegment information then we can derive three other data-subsegment informations.

- A bit counter is maintained to distinguish the current time unit is odd or even if the bit counter is 0 or 1. Given a pair of neighboring BSs U and D, where U and D located in the same column. Suppose that $U[i, j]$ and $D[i', j']$ denotes the data-subsegment information, two cases are formally stated below.
  - Case 1: If the bit counter is 0, then $i' = (j+3) \bmod 2n^2$ and $j' = (j+1) \bmod 2n^2$. Inversely, $i = (j'-1) \bmod 2n^2$ and $j = (i'-3) \bmod 2n^2$.
    - For instance as shown in Fig. 8(a), consider BSs $B_{1,1}[1, 10]$ and $B_{2,1}[13, 2]$, so $13 = 10 + \underline{3}$ and $2 = 1 + \underline{1}$.
  - Case 2: If the bit counter is 1, then $i' = (j+1) \bmod 2n^2$ and $j' = (i+3) \bmod 2n^2$. Inversely, $i = (j'-3) \bmod 2n^2$ and $j = (i'-1) \bmod 2n^2$.
    - For instance, as shown in Fig. 8(b), consider BSs $B_{1,1}[11, 2]$ and $B_{2,1}[3, 14]$, so $3 = 2 + \underline{1}$ and $14 = 11 + \underline{3}$.
- Given a pair of neighboring BSs L and R, where L and R located in the same row. Let $L[i, j]$ and $R[i', j']$ denotes the data-subsegment information, then $i' = (i+2n) \bmod 2n^2$ and $j' = (j+2n) \bmod 2n^2$. Inversely, $i = (i'-2n) \bmod 2n^2$ and $j = (j'-2n) \bmod 2n^2$.

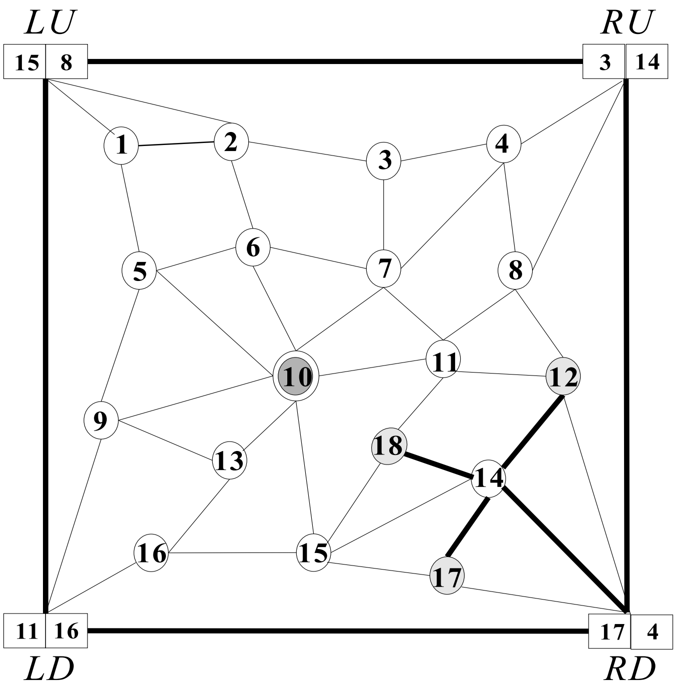

Figure 9: Four neighboring BSs.

- For instance as shown in Fig. 9, if $n = 3$ and $LU[15,8]$ and $RU[3,14]$ are a pair of neighboring base stations located in the same row, $3 = (15 + \underline{2 \times 3}) \bmod 18 = 3$ and $14 = (8 + \underline{2 \times 3}) \bmod 18 = 14$. For an another instance, if $LD[11,16]$ and $RD[17,4]$ are a pair of neighboring base stations located in the same row, $11 = (17 - \underline{2 \times 3}) \bmod 18 = 11$ and $16 = (4 - \underline{2 \times 3}) \bmod 18 = 14$.

Based on above formula, we can obtain other three data-segment informations if we just know one data-segment information. If we can acquire the four data-segment information, then we can determine a final path to one of he four BSs in order to wait for the first data-segment incoming. Obviously, the BSs with maximum value of $[d_1, d_2]$ of $B[d_1, d_2]$, where $B \in \{LU, LD, RU, RD\}$, will be elected to be the connecting BS. This indicates that the waiting time for the first data-segment will be minimum.

4.2 Error-Handling and Handoff Operations

One advantage of our scheme is to provide a fast recovery process if there is failed transmission and the handoff problem. Given a mobile host MH, let MH$[d]$ represents mobile host keeps S_d data-segment. Two conditions of reconnecting to BSs are stated below.

E1: **Error-Handling –** When the data transmission of a MH is failed, MH may redetermine a new BS such that the new BS has smaller value of d which is most near to d.

- For instance as shown in Fig. 10(a), the data transmission of MH[17], or node 10, which connects to *RD*, is failed, so node 17 will connect to *LD* since value 16 in $LD[11,16]$ is near to 17.

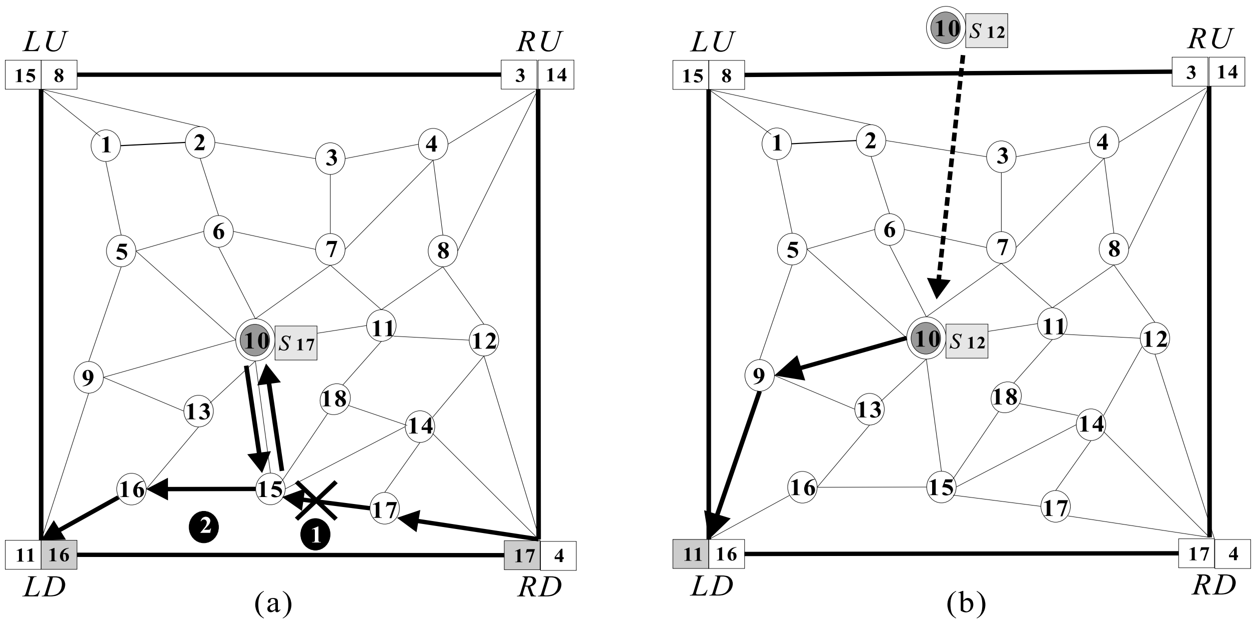

Figure 10: Examples of (a) failure transmission, and (b) handoff.

E2: **Handoff –** When a MH is leaving out the original cell area and enter into a new cell area, then a handoff process can be easily achieved by let MH connect to a new BS, where BS $\in \{LU, LD, RU, RD\}$, such that BS has smaller value than d and the proximate value of d. This operation may be connect to a multicast tree if the root of a existing shared-tree is the BS.

- For instance as illustrated in Fig. 10(b), a MH[12], or node 10, is roaming to a new cell area, so node 17 will connect to LD since value 11 in $LD[11, 16]$ is near to 12.

This indicates that our scheme and the integrated wireless network model can be used to effectively handle the failed transmission and handoff problems.

5 Performance Evaluation

One possible scheme is using snake-like ordering scheme. A possible of data transmission of snake-like scheme is also outlined as illustrated in Fig. 11(b). A comparison of the data-allocation of our and snake-like schemes is illustrated in Fig. 11(a). A video is partitioned into n^2 data subsegments, each length $\frac{l}{n^2}$, where l is original video length. Our scheme is split video with length l into $2n^2$ data subsegments, such that length of each data subsegment is $\frac{l}{2n^2}$. In the following, a data-transferring unit time is assume as $U = f(\frac{l}{2n^2})$ in our scheme, therefore $2U$ may be used for the snake-like scheme. The total time T_{total} includes waiting time $T_{waiting}$ and data-transmitting time $T_{transmit}$. Therefore, we have the following result.

$$T_{total} = T_{waiting} + T_{transmit}.$$

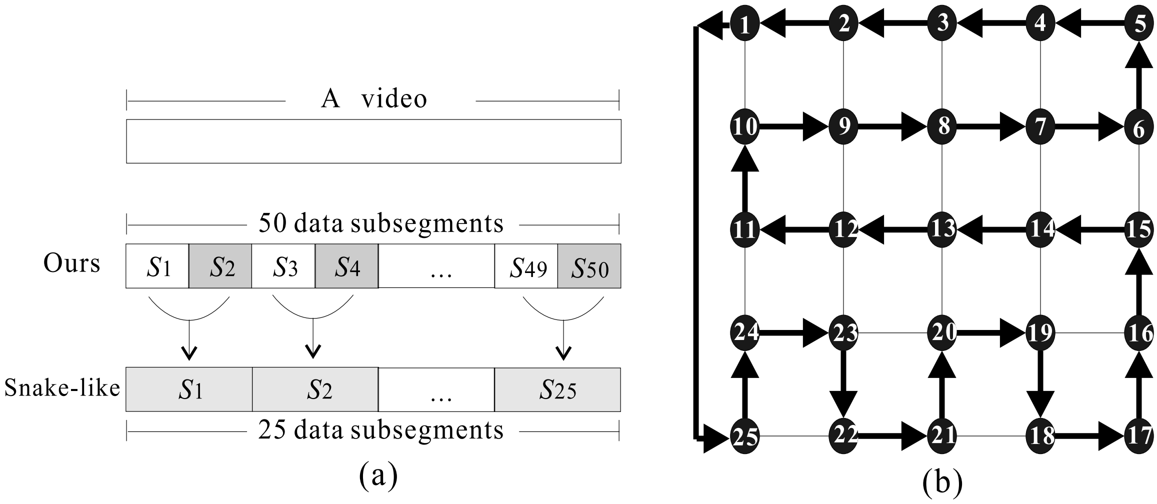

Figure 11: (a) The data partition and (b) data transmission of snake-like scheme.

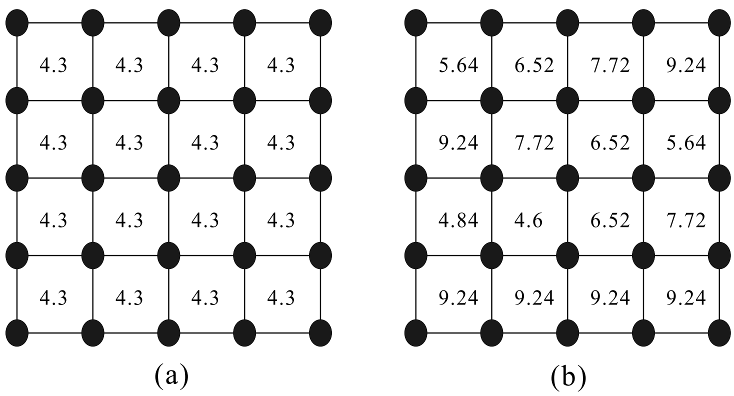

Figure 12: The average waiting time of (a) ours and (b) snake-like scheme in a $B_{5\times5}$.

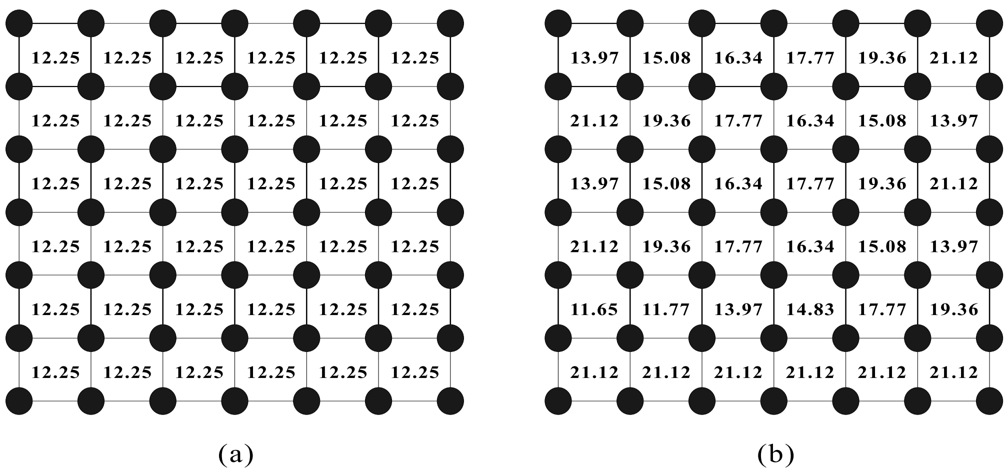

Figure 13: The average waiting time of (a) ours and (b) snake-like scheme in a $B_{7\times7}$.

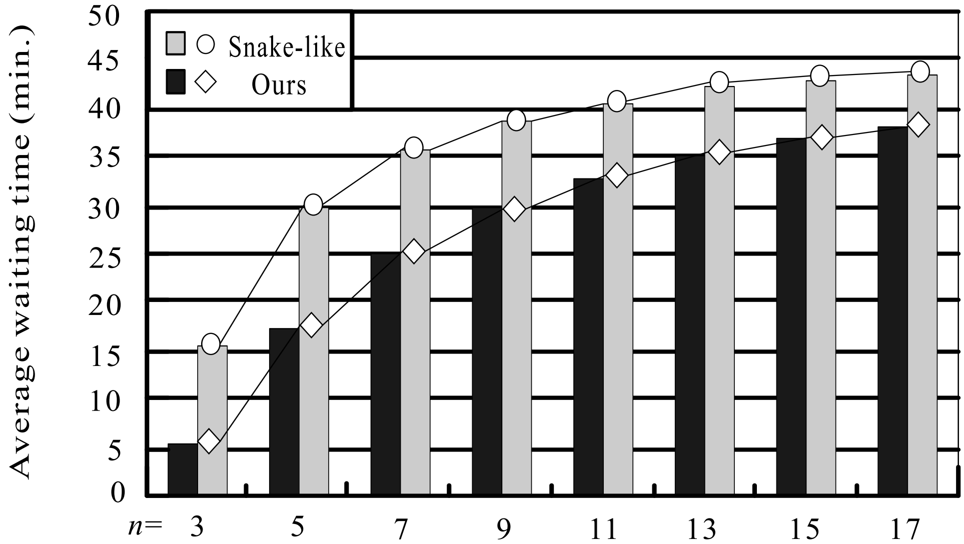

Figure 14: A comparison table of average waiting time vs. number of BSs.

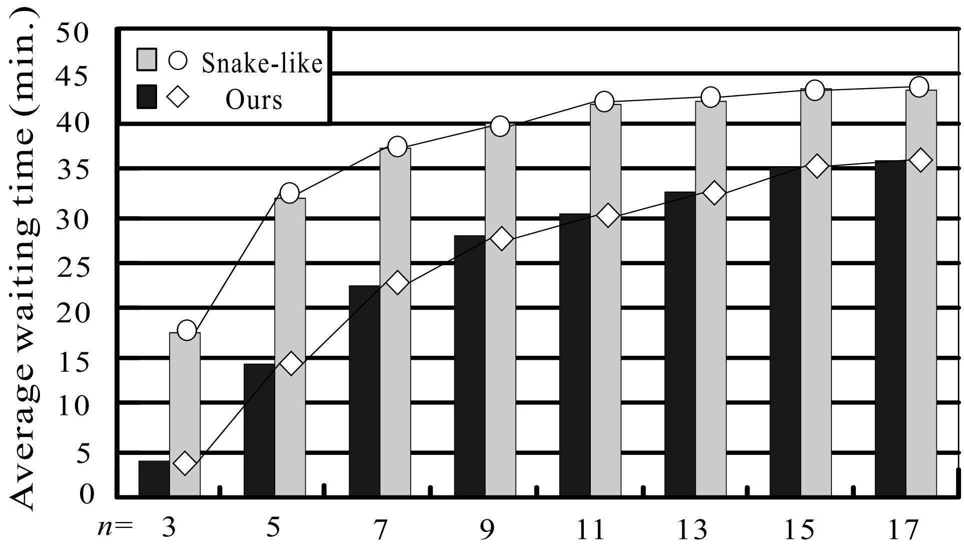

Figure 15: A comparison table of average waiting time vs. number of BSs.

It is observed that the time cost of T_{total} is mainly determined by value of $T_{waiting}$. Therefore, a simulation result is given to make a comparison of $T_{waiting}$ for our and snake-like schemes. The formula of the average waiting time formula of our scheme and snake-like scheme respectively are

$$\frac{\sum_{k=1}^{2n^2}((2n^2-M+1)*U)}{2n^2}$$

and

$$\frac{\sum_{k=1}^{n^2}((n^2-M+1)*\ 2U)}{n^2}$$

, where M is the maximal value of data subsegment in $\{LU, LD, RU, RD\}$ of a cell area. In our simulation, we let unit time $U = \frac{100}{2n^2}$ minute. For example, the average waiting time $T_{waiting}$ of $B_{5\times5}$ and $B_{7\times7}$ for our and snake-like schemes are illustrated in Fig. 12 and Fig. 13.

A formal comparison table of the average waiting time of our and snake-like schemes are given in Fig. 14, where n is varying from 3 to 17. The result of Fig. 14 is obtained by assumed that each cell area exists one MH which wait for the first data-segment S_1. It is observed that our average waiting time is better than snake-like scheme has.

To illustrate the effect of the average waiting time vs. the failure transmission. A simulation is done by making different assumption. Note that Fig. 15 is obtained by assumed that each cell area exists one MH but waits for the data-subsegment S_i, where $1 \leq i \leq 2n^2$. This indicates that the failure transmission is occurred during transmitting the data-subsegment S_i. From the result of Fig. 14 and Fig. 15, we observe that the average waiting time of our scheme is better than snake-like scheme. By comparing the simulation result of our scheme from Fig. 14 and Fig.15, it is worth noting that the average waiting time for the failure transmission is approximately equal to the new call has. It implies that the our scheme is a stable strategy. To conclude this section, it is beneficial to adopt our proposed scheme, which is evaluated by our simulation result.

6 Conclusion

In this paper, we investigate a broadcast-VOD problem in an integrated wireless mobile network. Existing wireless mobile networks can be classified into single-hop (such as GSM system) and multi-hop mobile networks (such as Ad-hoc network). A single-hop wireless mobile network is characterized by each base station (or BS) connecting to other BS through MSC (mobile station center) by a wired network, but each mobile host (or MH) communicating with its own BS within one-hop transmission radius. Our proposed wireless mobile network is an integration of single-hop and multi-hop mobile networks. The integrated network is characterized by each BS connecting to other BS by a wired network, but each MH communicating with a BS within multi-hop transmission steps. In our integrated network, BSs are connected by a 2-D tori interconnection network. In addition, an important application, called broadcast-VOD protocol, is presented in such an integrated network. Therefore, two contributions are presented in this paper: (a) a new integrated wireless mobile network is proposed, (b) a fast broadcast-VOD protocol is introduced in such a new network. In our strategy, VOD-data are well scheduled and broadcasted among 2-D tori-BSs such that the average waiting time is minimum. In each cell area, a VOD (Video On-Demand) is dynamically requested by any MH at the different time to dynamically construct a multicast tree, while the root node of multicast tree is a BS. This guarantees that each MH can receive the VOD-segment from its corresponding BS within minimal waiting time. Performance analysis justified that our proposed scheme outperforms existing schemes.

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