ABSTRACT
Multi-hop relaying is an important concept in tackling the inherent problems of limited capacity and coverage in cellular networks. It helps to solve the dead-spots problem and to ease congestion in hotspots. However, to obtain good performance of multi-hop relaying, an effective channel assignment scheme is needed. In this paper, we study the design goals of a good channel assignment scheme. We then propose a channel assignment scheme, called Extended Delay-Sensitive Slot Assignment (E-DSSA), which achieves all these goals. The distinctive feature of E-DSSA is the use of a novel transmission zone testing technique which allows high flexibility and precision in channel assignment in TDD W-CDMA multi-hop cellular environment. Performance evaluation shows that E-DSSA outperforms its existing counterparts in terms of data throughput with low delay for both sparse and dense networks. E-DSSA is also shown to adapt to different cell sizes achieving high throughput and call acceptance ratios.

Categories and Subject Descriptors
C.2.1 [Computer-Communication Networks]: Network Architecture and Design - wireless communication; C.2.5 [Computer-Communication Networks]: Local and Wide-Area Networks - access schemes

General Terms
Design, Performance

Keywords
Multi-hop relaying, cellular, TDD W-CDMA, channel assignment, directional antenna, and performance evaluation.

1. INTRODUCTION
Third generation (3G) wireless networks have adopted wideband Code Division Multiple Access (W-CDMA) technology. While the use of W-CDMA allows data-rates up to 2 Mbps, inherent limitations on capacity and coverage of these networks still exist. These networks suffer from the problems of dead-spots and hotspots (congested areas). Recently, several multi-hop relaying proposals [2, 3, 5, and 8] were introduced to address some of these limitations and problems.

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Figure 1. Comparison between the cases: a) omni-directional antenna

Figure 1. Comparison between the cases: b) directional antenna with flexible transmission range

Among them [8] are solutions that utilize the contention-free W-CDMA medium access, using directive antennas to increase channel reuse and reduce interference and power consumption, and using Global Positioning System (GPS) to facilitate the routing [10]. However, improper channel assignment could induce high packet delay and signal collisions. In fact, the design goals of a “good” channel assignment scheme should include, to name a few, high throughput, low packet delay, and high channel reusability. Previously, we introduced a heuristic fixed channel assignment scheme, called Delay-Sensitive Slot Assignment (DSSA) [1], which achieves most of the design goals except that DSSA is suitable only for the relaying environment where omni-directional antenna and mobile devices that send and receive data at the same time are used. The idea of DSSA is based on neighborhood information with lowering time-slot waiting time. For example, in Figure 1a, when a channel is proposed for a mobile node A whose next hop node is node B, then a) none of the neighbors (nodes C and D) of node A should be receiving on the proposed channel and b) none of the neighbors (nodes D and E) of the next hop node B is transmitting on the proposed channel; otherwise, the proposed channel cannot be assigned. Obviously, in the environment with directional antennas, this neighborhood information is no longer adequate (See Figure 1b).

a) Omni-directional antenna

b) Directional antenna with flexible transmission range

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E-DSSA uses a novel transmission zone testing technique which allows high flexibility and precision in channel assignment in these networks. E-DSSA also fulfills the design goals of a good channel assignment scheme. Simulation results show that E-DSSA outperforms DSSA and the single-hop case in terms of data throughput with low delay. E-DSSA can also adapt to a larger cell size to achieve considerable throughput and call acceptance ratio even in a sparse network.

This paper is organized as follows. In the next section, we provide a detailed examination of the design goals of a channel assignment scheme and propose ways to achieve these goals. In Section 3, the E-DSSA scheme is introduced. The simulation model and results are presented and discussed in Section 4. Section 5 concludes the paper.

2. CHANNEL ASSIGNMENT

In this section, we examine the design goals of a good channel assignment scheme for 3G TDD W-CDMA cellular networks and suggest ways to achieve them. The design goals are:

1. High Throughput

In TDD W-CDMA multi-hop cellular environment, the throughput degrades because of co-time-slot and/or co-channel conflicts. The throughput also depends on the degree of channel reusability and the chance of signal collisions. By using some rules and transmission zone testing for checking, the conflicts and signal collisions can be avoided and high channel reusability can be achieved. We will explain these conflicts, rules, and checking method later in this section.

2. Low packet delay

Multi-hopping induces delay on each hop on a route. When TDD mode is used and a packet arrives at a relaying node\(^1\), it has to wait until its time-slot for sending out. The time-slot waiting time (delay) should be minimized to achieve overall low packet delay. Assigning consecutive time-slots on each node on a route helps to reduce the time-slot waiting time. For example, if a mobile node is assigned with time-slot 3, its next hop node in the direction of the destination node should be assigned with time-slot 4.

3. Applicability to general mobile devices

Some mobile devices send and receive signals at the different time and some mobile devices do not. For the former case, assigning a channel to the current node with the same time-slot as that of the channel of the next hop node would cause packet loss because the next hop node is simply not ready to receive the packet. We call this co-time-slot conflict. For the latter case, the receiving channel must be different from the transmitting channel of the same mobile node; otherwise, signal collision will occur. We call this co-channel conflict. By using some rules, these conflicts could be avoided.

4. Resilience to signal collision

When a directional antenna is used, using the neighborhood information to avoid signal collision is no longer adequate. Hence, we suggest a transmission zone testing methodology for channel conflicting checking. This testing is applicable to both omni-directional and directional antennas. For example, in Figure 1b, when proposing a channel to node A for the path (A-B-X), it just need to make sure that a) the nodes (D and B) within the transmission zone of node A are not receiving on the channel, and b) the nodes (excluding A) with their transmission zone containing the next hop node B is not assigned or transmitting on the channel. Note that if the channel is assigned successfully, node B will use this channel to receive the signals from A.

5. Flexibility

Using transmission zone testing has another advantage, namely, that the transmission range is not restricted to be short. That is, the base station (BS) cell size is not required to be small. This is especially important in a W-CDMA or CDMA network because the cell capacity varies with the cell size (coverage) which is a well-known phenomenon, called cell breathing [4, 7]. Larger cell size allows higher network reachability. However, single-hop long range transmission and multi-hop short range transmission may co-exist inside a cell. This gives higher change of signal collisions. Node F, in Figure 1b, is an example. Transmission zone testing can handle this situation.

6. Effective, high channel reusability, and high radio resource utilization

Not all the nodes in the network are required to undergo channel information processing. Only the nodes falls in the transmission zone are required to be checked. Eliminating unnecessary nodes reduces the algorithm processing time and, thus, increases the effectiveness. Transmission zone testing is designed for this purpose. For example, in Figure 1b, node C does not fall into the transmission zone of node A. Information processing of node C is not required. Also, as there is no node with their transmission zone containing the next hop node B, no nodal information processing is required. Selecting inappropriate mobile nodes for checking may cause erroneous channel elimination that would reduce the channel reusability and, thus, the radio resource utilization.

3. EXTENDED-DELAY SENSITIVE SLOT ASSIGNMENT (E-DSSA)

We now propose the Extended Delay-Sensitive Slot Assignment (E-DSSA) scheme which is a centralized heuristic fixed channel assignment scheme for Multi-hop TDD W-CDMA cellular network that satisfies the design goals presented in the previous section. E-DSSA resides and is executed in the radio network controller (RNC) of a 3G Universal Mobile Telecommunication System (UMTS) network [4] (See Figure 2). The RNC has the global information on the position, data-rate, route, and channel assignment of all mobile nodes involved in communications.

![Figure 2. 3G UMTS network components.](image)

3.1 Description of E-DSSA

Given a route with a source node, intermediate nodes, a destination node (BS), and a limited number of channels, E-
DSSA reuses the available channels to achieve high throughput and low packet delay. A channel is represented by the pair (TS, C), where TS is the time-slot number and C is the code (spreading code [4]) number. E-DSSA consists of two phases: the Elimination phase and Selection phase. In the Elimination phase, rules \( a \) and \( b \) are used to avoid co-channel or co-time-slot conflicts. Rules \( c \) and \( d \) are used to avoid signal collisions by using transmission zone testing. The Selection phase is to select a candidate channel that contributes the lowest time-slot waiting time (delay) along the route. Figure 3 shows the E-DSSA scheme.

**Elimination phase**:

**Rule a.** The current node itself is not receiving on the proposed channel* (time-slot** of the proposed channel.)

**Rule b.** The next hop node is not transmitting on or temporary assigned with the proposed channel* (time-slot** of the proposed channel).

**Rule c.** Nodes on the other routes having their transmission zones*, in which the next hop node falls, are not transmitting on the proposed channel.

**Rule d.** Nodes that are in the transmitting zone* of the current node are not receiving on the proposed channel.

* - Avoiding co-channel conflicts. ** - Avoiding co-time-slot conflicts. * - Transmission zone testing.

**Selection phase**:

• The candidate channel that contributes the lowest time-slot waiting time (delay) of the route is selected.

In Figure 3, when E-DSSA receives a channel assignment request for an input route, it starts to assign a channel to the last hop node (\( Nd_{last} \)) on the route (Line A2), e.g., node C in Figure 4a. E-DSSA selects an available channel with highest time-slot from the channel pool of the BS (Selection). The proposed channel is tested by using rules \( a \) and \( c \) (Elimination). If this channel does not violate the rules, this channel is assigned to \( Nd_{last} \); otherwise, this channel is eliminated and E-DSSA continues the search for an available non-tried channel with highest time-slot for this node (Line A4-A7). If \( Nd_{last} \) is assigned a channel, E-DSSA starts to assign a channel for the second last hop node (Line A9), e.g., node B in Figure 4a. A channel with a time-slot that is successive and closest to the time-slot of the assigned channel of \( Nd_{last} \) is selected as the proposed channel to minimize the time-slot waiting time (delay) of packet (Selection). The proposed channel is then tested by using rules \( a \), \( b \), \( c \), and \( d \) (Elimination). If no rules are violated, this channel will be assigned to the node. If only rule \( a \) is violated, E-DSSA tries another code with the same time-slot of this channel (Line A15-A16). If channel assignment still fails, E-DSSA tries another available channel with the next highest time-slot (Line A10-A17). If channel assignment is a success, E-DSSA assigns a channel for the next successive node on the route (Line A18), and so on. If any node on the route failed to be assigned a channel, the channel assignment process will re-start from \( Nd_{last} \) with another non-tried available channel from the channel pool of the BS (Line A3-A19). The re-starting position could also be at the next hop node of the node that fails to be assigned a channel for this request.

### 3.2 Illustration of E-DSSA Scheme

Consider the path A-B-C-BS in Figure 4a. The last hop node C is considered as the current node. The next hop node is BS. Assume the channels (8, 1) and (8, 2) are already assigned to C for other routes. For mobile nodes that can send and receive signals at the same time, channels (7, 1), (7, 3), and (4, 1) are eliminated because they violate rules \( a \) (co-channel conflict) and \( d \) (signal collision), respectively. For mobile nodes that can either send or receive signals at one time, any channel with time-slot 7 and channel (4, 1) are eliminated because they violate rule \( a \) (co-time-slot conflict) and \( d \) (signal collision), respectively. Any other available channels with the highest time-slot in the channel pool of BS can be selected for C. Assume (8, 3) is this channel.

### A) Channel Allocation

1. Input a route from an entity
2. Assign \( Ch \) starting from \( Nd_{last} \) (i.e., \( Nd_{curr} \))
3. Do
   4. Do SELECT a non-tried available \( Ch \) with highest TS in \( Ch_{pool} \) and the capacity of this TS has not been used up
5. If \( Nd_{curr} \) not receiving on this \( Ch \) (Rule a)
6. If \( Nd_{curr} \) not receiving on this \( Ch \) (Rule d)
7. If channel assignment fails and non-tried available \( Chs \) exist.
8. If \( Ch \) assignment of \( Nd_{curr} \) is successful
9. Do take successive node on the route as new \( Nd_{curr} \)
10. Do SELECT an available \( Ch \) with closest TS to that of \( Nd_{curr} \) and capacity of this TS has not been used up
11. Do
12. (Rule a) If \( Nd_{curr} \) not receiving on this \( Ch \) (Rule b)
13. (Rule b) \( Ch \) assignment of \( Nd_{curr} \) is success.
14. Else
15. Select a non-tried Code of this TS.
16. While (\( Ch \) assignment fails and non-tried Codes exist)
17. While (\( Ch \) assignment fails and non-tried \( Chs \) exist)
18. While (\( Ch \) assignment fails and non-tried Codes exist)
19. While (\( Ch \) assignment fails and non-tried \( Chs \) exist)
20. Reply with \( Ch \) assignment result and update \( Ch \) information

* - Co-channel conflict constraint

** - Co-time-slot conflict constraint

* - Transmission zone testing

### B) Channel De-allocation

1. Input a route
2. De-allocate the Channels of each node on the route.

**Definitions**:

- **Current Node** (\( Nd_{curr} \)) is a node to be proposed a channel.
- **Next Hop Node** (\( Nd_{next} \)) is next hop node of current node.
- **Last Hop Node** (\( Nd_{last} \)) is nearest node to destination node (BS).
- **Node** (\( Nds \)) is a source node or relaying node.
- **Time-slot** (\( TS \)) is a time interval (slot) of a frame.
- **Code** is spreading code [5] in CDMA systems.
- **Channel** (\( Ch \)) is a Time-slot Code pair (TS, C).
- **Channel Pool** (\( Ch_{pool} \)) is a pool of available channels in BS.
- **Channel Table** stores channel information.
- **Channel Allocation Table** stores channel information in BS.
- **Transmission Zone** (\( Txzone \)) is coverage of antenna.

![Figure 3. E-DSSA Scheme.](image-url)
Figure 4b shows the channel assignment for node B. For mobile nodes that can send and receive signals at the same time, all the channels (except (5, 1) and (4, 1)) are eliminated because they violate the rules a, b, c, and d (See Table 1). For mobile nodes that can either send or receive signals at one time, all the channels in the figure (except (5, 1) and (4, 1)) and any channel with time-slot 8 and 6 are eliminated because they violate the rules a, b, c, and d (See Table 2). Since (8, 3) is already assigned to the next hop node C for the route A-B-C-BS, (7, 4) or any channel with (delay).satisfies all the rules and can be proposed to A. In this case, for this route. For source node A, any channel other than (6, 1) channel for node B to minimize the packet time-slot waiting time for this route. For source node A, any channel other than (6, 1) satisfies all the rules and can be proposed to A. In this case, channel (6, 2) is chosen for minimizing the time-slot waiting time (delay).

Figure 4. Channel assignment for a) node C, and b) node B of the path A-B-C-BS.

Table 1. Eliminated channels for B if nodes can send and receive signals at the same time

<table>
<thead>
<tr>
<th>Eliminated channels</th>
<th>rule</th>
<th>remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(6, 1)</td>
<td>a</td>
<td>Co-channel conflict</td>
</tr>
<tr>
<td>(8, 1), (8, 2), (8, 3)</td>
<td>b</td>
<td>Co-channel conflict</td>
</tr>
<tr>
<td>(3, 1), (7, 1), (7, 2), (7, 3)</td>
<td>c</td>
<td>Signal collision</td>
</tr>
<tr>
<td>(2, 1), (7, 1), (7, 3)</td>
<td>d</td>
<td>Signal collision</td>
</tr>
</tbody>
</table>

Table 2. Eliminated channels for B if nodes can either send or receive signals at one time

<table>
<thead>
<tr>
<th>Eliminated channels</th>
<th>rule</th>
<th>remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>all channels in time-slot 6</td>
<td>a</td>
<td>Co-time-slot conflict</td>
</tr>
<tr>
<td>all channels in time-slot 8</td>
<td>b</td>
<td>Co-time-slot conflict</td>
</tr>
<tr>
<td>(3, 1), (7, 1), (7, 2), (7, 3)</td>
<td>c</td>
<td>Signal collision</td>
</tr>
<tr>
<td>(2, 1), (7, 1), (7, 3)</td>
<td>d</td>
<td>Signal collision</td>
</tr>
</tbody>
</table>

4. PERFORMANCE EVALUATION

In order to quantify the performance gain of the E-DSSA scheme, its performance is compared to the DSSA scheme [1] and the single-hop case. We also evaluate the performance of E-DSSA with directive antennas with different cell sizes.

4.1 Simulation Model and Parameters

Our simulation model is a single cell with 70 source nodes. The number of relaying nodes varies from 0 to 160 in increments of 40. The source nodes and relaying nodes are uniformly distributed over a circular area with a radius of 1 km centered at the BS. We separate the role of source node and relaying node so that the case in which no mobile nodes are willing to relay signals can be captured. We study the following two scenarios.

Scenario 1: (omni-directional antennas)

In this scenario, we will study the effect of the number of relaying nodes on the performance of E-DSSA, DSSA and single-hop case with omni-directional antennas and mobile nodes that can either send or receive signal at one time are used. Table 3 shows the simulation parameters. For the single-hop case, the BS cell size is 1000m and the cell capacity 125 kbps. For the multi-hop (E-DSSA and DSSA) cases, the cell size of BS and the transmission range of mobile node is 250m. The capacities of BS and mobile node are 1 Mbps. Each TDD data transmission frame is 10 ms long and has 15 time-slots [4]. The numbers of uplink and downlink transmission time-slots of BS are 13 and 2 respectively. Time-slot assignments for mobile nodes depend on the channel assignment scheme used. Each time-slot can be assigned at most 16 spreading codes and each code corresponds to a data rate of 13.8 kbps. Each call (connection) uses one code at a constant bit rate. Each source node generates call requests at an average rate of 0.1 calls per second following a Poisson distribution. The average duration of each call is 5 seconds with an exponential distribution. The maximum number of hop is set to 7. The duration of simulation is 60 seconds. The simulation is modeled with OPNET Modeler 10.0A [6].

Table 3. Simulation parameters for Scenario 1

<table>
<thead>
<tr>
<th></th>
<th>E-DSSA</th>
<th>DSSA</th>
<th>Single-hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS cell size (radius)</td>
<td>250 m</td>
<td>1000 m</td>
<td></td>
</tr>
<tr>
<td>BS cell capacity (data-rates)</td>
<td>1 Mbps</td>
<td>125 kbps</td>
<td></td>
</tr>
<tr>
<td>Mobile node transmit range (distance)</td>
<td>250 m</td>
<td>1000 m</td>
<td></td>
</tr>
<tr>
<td>Mobile node capacity</td>
<td>1 Mbps</td>
<td>125 kbps</td>
<td></td>
</tr>
<tr>
<td>Mobile node type</td>
<td>Either send and receive data at one time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS uplink timeslot</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS downlink timeslot</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data-rate per code</td>
<td>13.8 kbps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. available codes / slot</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Call request rates</td>
<td>0.1 calls/sec.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Call holding time</td>
<td>5 sec.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antenna</td>
<td>Omni-directional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum hop count</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation duration</td>
<td>60 sec.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Scenario 2: (directional antennas with different cell sizes)**

In this scenario, we study the performance of E-DSSA with directional antennas based on two different cell sizes. Note that, in Figure 5, nodes x and y cannot reach the BS if the small cell size is used. The parameters are the same as scenario 1 except the transmission range and capacity of the BS and the last hop node and the antenna setting (See Table 4). This scenario is used to demonstrate the flexibility of E-DSSA that can adapt different cell sizes.

![Scenario 2: Network simulation model for a) small cell size, and b) larger cell size.](image)

**Table 4. Simulation parameters for scenario 2 which are different from that of scenario 1**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>E-DSSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS cell size (radius) or last hop node transmit range (distance)</td>
<td>250 m</td>
</tr>
<tr>
<td>BS cell or last hop node capacity (data-rates)</td>
<td>1 Mbps</td>
</tr>
<tr>
<td>Antenna</td>
<td>Directional with 45° beam angle</td>
</tr>
</tbody>
</table>

Although a single cell model is used in both scenarios, it is not difficult to generalize it to multiple cells environment as long as a proper handoff mechanism is provided. In this simulation, we assume the nodes to be static (or with limited mobility) because our focus is to quantify the differences in throughput and delay between E-DSSA, DSSA, and the single-hop case. In both E-DSSA and DSSA simulations, we use Euclidean shortest paths for relaying. We also assume perfect power control, perfect physical medium, perfect time-slot synchronization, and each mobile node has enough battery capacity for relaying signals. As W-CDMA is used as the multiple (medium) access technique, other MAC protocols, viz. the IEEE 802.11 protocol is no longer needed.

**4.2 Performance Metrics**

The metrics used in our performance evaluation are described below. In particular, the BS uplink throughput and end-to-end delay are used for Scenario 1 while all the metrics are used for Scenario 2.

**BS Uplink Throughput** – the number of packets that the BS receives per second. **End-to-End Delay** - the time required for a packet sent from the source node to BS. **Network reachability** – the ratio of the number of source nodes whose signals can reach the BS to the total number of source nodes. **Call acceptance ratio (AR)** – the ratio of the number of accepted calls to the total number of calls. **Call blocking ratio (BR)** – the ratio of the number of blocked calls to the total number of calls.

High throughput and high AR represents a good combination of cell capacity and the demand (number of source nodes) being served. The servable demand depends on the network reachability and the effectiveness of the channel assignment scheme. The end-to-end delay depends on the effectiveness of the channel assignment scheme as well.

Note that we consider three types of calls: accepted calls, blocked calls, and potential calls. Accepted calls and blocked calls are reachable calls. Potential calls are those calls that can reach the BS if the BS cell range is large enough. We define the potential calls to account for the following situation. In a sparse network, a small cell size (large capacity) could have a high AR but a low throughput simply because most of the calls cannot reach the BS (See Figure 5). Any call that can reach the BS will be accepted because most of the cell capacity is not being used. In contrast, a dense network could generate a low AR and high throughput because most of the potential calls can reach the BS, but the large cell capacity is still insufficient for the high demand and most of the new calls are blocked.

**4.3 Simulation Results**

**Scenario 1: (omni-directional antennas)**

**BS Uplink Throughput/ End-to-end Delay**

In Figures 6 and 7, when the number of relaying nodes (RN) is zero, the BS throughput and end-to-end delay of E-DSSA and DSSA are small because many source nodes cannot reach the BS to use the available cell capacity and single-hop communications dominate, respectively. As the RN increases, the BS throughput and end-to-end delay of both E-DSSA and DSSA increases because more source nodes can reach the BS through multi-hopping. Note that E-DSSA has a higher throughput than DSSA. This is because DSSA suffers from co-time-slot conflict, which causes packet loss. When the RN further increases, this allows more and longer multi-hop routes that induce more co-time-slot conflicts in DSSA. E-DSSA is able to handle the conflict and, thus, higher throughput is maintained. Both E-DSSA and DSSA have similar pattern of end-to-end delay which is not high as compared to that of the single-hop case because they both are able to minimize the time-slot waiting time. When the RN is larger than 80, the delay is steady and because the delay is bounded by the maximum hop count. For the single-hop case, while end-to-end is low (as there is only single hop communication), the throughput is limited because the cell capacity is too small to meet the demand.

**Scenario 2: (directional antennas with different cell sizes)**

**BS Uplink Throughput/ End-to-end Delay/ Network Reachability/ Call acceptance Ratio/ Call blocking ratio**

Consider the results in Figures 6 and 8, when a cell size of 250m is used, the throughput of E-DSSA with directional antennas has little difference from the case with omni-directional antennas because the cell capacity is not large enough such that the capacity is used-up before the codes are used-up. Thus, the effect of channel reuse becomes less significant.

Consider the graphs in Figures 8, 9, 10, and 11. For both cases (R=250m and R=370m), when the RN is small, the network reachability, throughput, AR, and BR are low. As the RN increases, the values of these metrics increase. Note that, in terms
of throughput and AR, a larger BS cell size favors a sparse network whereas a smaller cell size favors a dense network. This is because when the RN is small, a larger cell size has a higher network reachability such that more source nodes can reach the BS to use the available capacity. When the RN is large, network reachability is no longer an issue, but the cell capacity is. Thus, a larger cell capacity, i.e., a smaller cell size, is preferred so that more source nodes can be served. E-DSSA adapts different cell sizes to achieve high throughput and AR. As the end-to-end delay of E-DSSA in both cases differs little from that of scenario 1, the delay results are not presented here because of the lack of space.

5. CONCLUSIONS AND FUTURE WORK
In this paper, we proposed the Extended Delay-Sensitive Slot Assignment (E-DSSA) scheme for TDD W-CDMA multi-hop cellular networks which achieves the design goals of a good channel allocation scheme including high throughput, low packet delay, strong resilience to signal collision, high flexibility and effectiveness, high channel reusability and radio resource utilization by formulating rules to avoid co-channel or co-time-slot conflicts, and by using transmission zone testing to avoid signal collisions. Simulation results show that E-DSSA has a much higher throughput and a similar low end-to-end delay compared with DSSA and a single-hop case. E-DSSA also adapts different cell sizes to achieve high throughput and call acceptance ratio.

User mobility, routing, and handoff would affect the overall performance of the channel assignment scheme. The effect of such issues is currently being investigated. In addition, the BS cell size contributes an important factor to the network performance. We are currently working on a multi-hop cellular architecture which addresses the optimal cell size issue [9].

6. REFERENCE