VIRTUAL CONNECTION TREE OVER MULTIPLE ACCESS TECHNIQUES FOR 3G WIRELESS COMMUNICATION SYSTEMS

A. Heath and R.A. Carrasco

School of Engineering and Advanced Technology, Staffordshire University

PO BOX 333, Beaconside, Stafford ST18 0DF, Staffordshire, U.K.

Emails: A.L.Heath@staffs.ac.uk, R.A.Carrasco@staffs.ac.uk

Abstract: This paper evaluates a Virtual Connection Tree (VCT) algorithm for mobile Asynchronous Transfer Mode (ATM) handoff that offers service adaptability and efficient allocation of wired resources is applied to different multiple access techniques. This creates a more distributed system where decisions about traffic conditions in different areas can be evaluated at the Base Station (BS) level and not the Master Switching Centre (MSC) level.

Keywords: 3G, VCT, ATM, Mobile Communications

1 Introduction

In future third generation (3G) systems it is anticipated that wireless, wired and satellite communications will be integrated in one system where multimedia data will be transferred at bit rates up to 2Mbits/sec [1]. Data traffic is growing at a much faster rate than voice, so new and efficient mediums are required to transport this information [2]. A medium that can be used to integrate multimedia traffic is ATM technology, which is a wired infrastructure that provides excellent QoS [3-5]. This paper presents a way in which Mobile ATM can be used to improve the QoS for many users in a network.

Extensive research has been conducted to determine the best multiple access technique for future mobile communication systems where CDMA, TDMA, PRMA, FDMA and combinations of these are employed [6-8]. This paper considers the advantages of applying the VCT algorithm developed in [9,10] to each of the aforementioned technologies. In the future it is thought that the MSC will be removed from the system model, as in ad-hoc networks and that Internet Protocol (IP) traffic may be transmitted over an ATM backbone [11], due to the QoS guarantees.

It has been demonstrated in [12] that the service adaptable handoff algorithm can be applied to data rates of up to 2Mbits/sec and above without significant degradation of service. A solution to the mobile handoff problem was illustrated in [13] in which the MSC is not involved with the handoff but wired resources are wasted unlike the proposal in [12]. Using the Call Admission Control Algorithm which is presented in [9, 10, 12] and developed in this paper a more distributed system is created.

Section 2 examines how the VCT can be applied to various multiple access techniques, while section 3 presents call/carrier communication algorithm. Section 4 details the simulations and a discussion of the results and finally section 5 is used to draw conclusions and suggestions of future work.

2 Virtual Connection Tree

VCT is an ATM oriented strategy that avoids the need to involve the MSC during handoffs [12]. The VCT consists of cellular BSs with radio transceivers connected to switching nodes thorough and ATM wired infrastructure and mobile stations (MS), which transmit information over the shared radio link.

In order to apply the VCT to the multiple access scheme, at call set-up each MS connection is assigned at the Virtual Connection Identifier (VCI) in the VCT. Each VCI is uniquely associated to a carrier for time division duplex (TDD), or a pair of carriers for frequency division duplex FDD. The VCI-VPI combination represents the carrier and BS used at any moment by a given connection. The numbering structure is shown in Figure 1. Each BS is associated to a Virtual Path Identifier (VPI) and each mobile connection is assigned a group of VCIs, each VCI corresponding to a carrier. During a handoff the VPI changes, indicating a new BS and the VCI could change indicating a change in carrier.

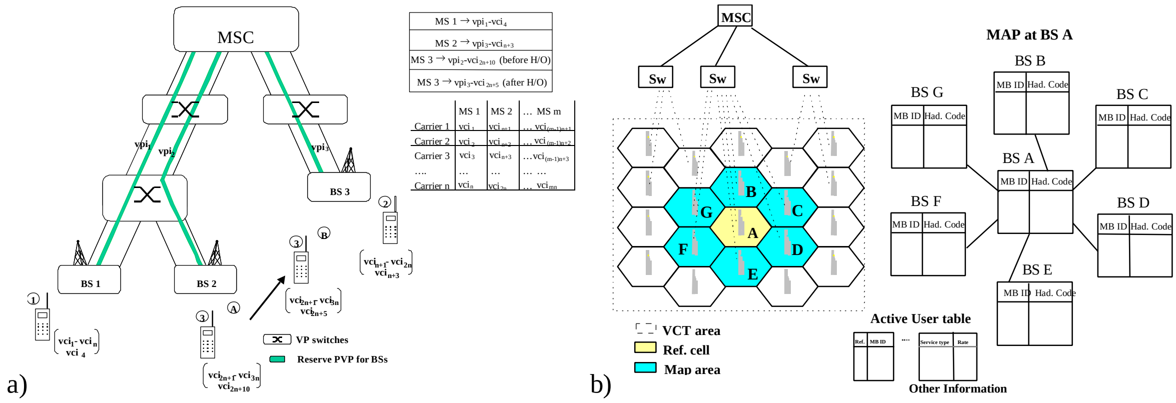


Figure 1 –a)VCT-CRDMA Integration, b) VCT, Carrier-map and tables

The handoff procedure for MS 3 is illustrated in Figure 1. The VPI-VCI information allows the MSC to locate any MS at any time, cells are routed correctly given this information.

By using the VCT with multiple access techniques no handoff processing is carried out at the MSC since all possible routes are pre-established. This implies a reduction in the amount of signalling and processing during a handoff, which improves the GoS. The traffic can be evaluated at the MSC since the VCNs provide the carrier frequency and BS information of every mobile without any additional signalling.

3 Carrier Communication Algorithm

In [11] a carrier communication algorithm was presented. This involves passing in real-time, the information gathered at the MSC to all BSs in the VCT, such that a BS creates a 'map' of the carriers used in adjacent cells. Each BS has its table similar to that in CSMA, which contains information about its own and interfering cells. The size, S of this table, the carrier-map table, depends on the number of cells considered as interferers, B_i as well as the maximum number of carriers/codes allowed in each BS, C, and is given by Equation 1.

$$S = (B_i + 1)C \tag{1}$$

Another table is also required, the VCT active user table, in which all active users are registered relating to the MB ID number. The tables and the area they refer to are illustrated in Figure 1b. Both tables are immediately updated when changes such as new connections, handoffs and terminations occur within the VCT. The active user table is only affected by connection set-ups and terminations. The carrier-map can be updated in one of two ways; if the change is inside the cell, the BS directly updates its own table. If the change occurs outside its cell, the BS waits for the information from MSC. The set-up and termination processes are shown in Figure 2a) and The handoff process is illustrated in Figure 2b).

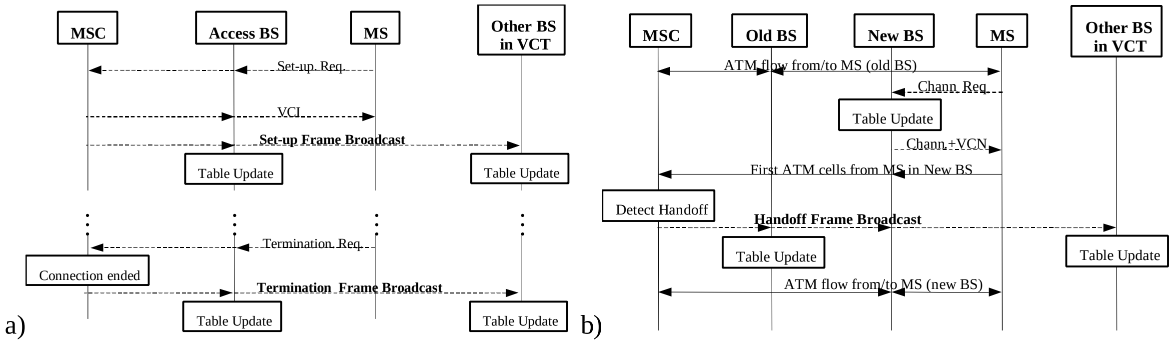


Figure 2 – a) Set-Up and Termination Process b) Handoff Process

Each change requires a different frame to be generated by the MSC, these are shown in Figure 3.

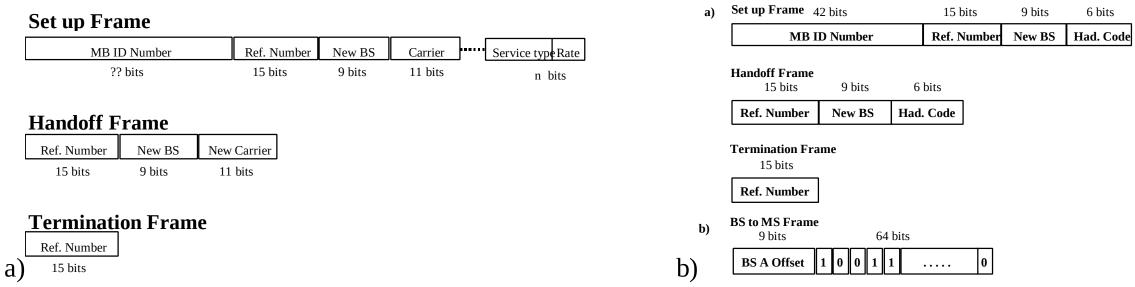


Figure 3– a)TDMA, FDMA, PRMA CCA, b) CDMA Frames

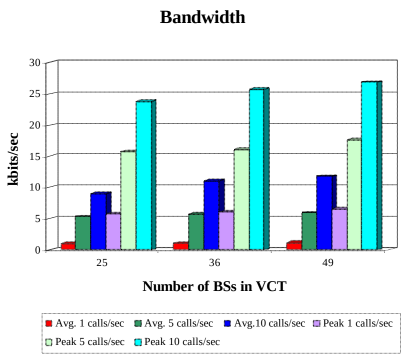
The carrier/code communication algorithm introduces distributed dynamic channel allocation schemes (FDMA, TDMA, PRMA) can easily be implemented since information about frequency usage is provided so the amount of interference is reduced. The system is distributed since BSs store information gathered and administer call admission control. In CDMA this is also useful as the MS can use this information to cancel out the interference from these cells.

4 Evaluation, Results and Discussion

A combination of the VCT-multiple access technique and carrier/code communication algorithm is evaluated. The bandwidth required for the carrier communication algorithm is determined. A comparison between FCA and DCA for TDMA, FDMA and PRMA and the advantages in CDMA are then evaluated. The saved amount of signalling at the MSC is then evaluated, when calls are admitted/declined at BS level. A cellular system is used to simulate these situations, using the parameters according to Table 1.

The signalling bandwidth was measured by adding the bandwidth for the carrier/code communication algorithm, set-ups, handoffs and terminations. The bandwidths are illustrated in Figure 4, where the peak values are worst case conditions.

The peak bandwidth varies from 5.76kbits/sec (15 ATM cells/sec) for 25 BSs at 1 call/sec generated, to 26.88kbits/sec (70 ATM cells/sec) for 49 BSs at 10 calls/sec. The bandwidth demand is small considering the rates used in ATM networks (150Mbit/sec). This occupancy may be reduced if the signalling channel is shared with other control information.



Area (M)	77.94 miles2
No. of BS	16
Call gen rate (avg, µ)	1, 5, 10 call/sec
Simulation Duration	500 3600 sec
Channels per BS	50
Cluster sizes	3, 4 and 7
No. channels and slots	FDMA 50; 1
	TDMA 17; 3
	PRMA 5; 10
Speed	20 - 70 miles/h
Length	30 - 240 sec.
Directions (max)	8

Figure 4 - MSC-BS Bandwidth. **Table 1**

FCA and DCA are now compared in terms of failing probabilities for the VCT applied to different multiple access techniques. With FDMA a system consisting of 16BSs each with 50 channels is considered. For a given failing probability DCA allows a higher intensity of traffic than FCA, until about 4%, see Figure 5. Improvements with respect to FCA of 0.87, 0.63 and 0.48 Erlang/mile^2 are shown for cluster sizes of 7, 3 and 4 respectively at a failing probability of 1%. DCA increases the capacity of the system, so more connections are admitted and less ongoing calls are dropped. If the cell size is reduced the traffic intensity can increase compared to that with FCA.

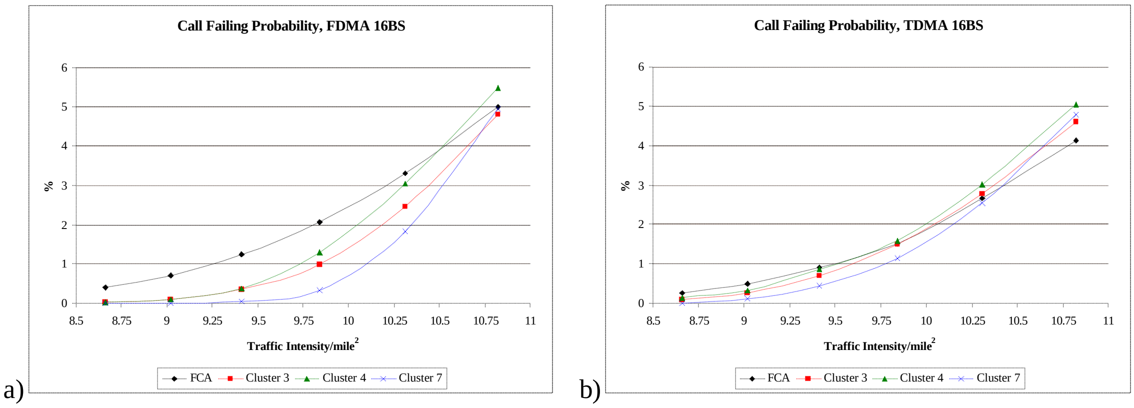


Figure 5- Failing Probability –a) FDMA b) TDMA

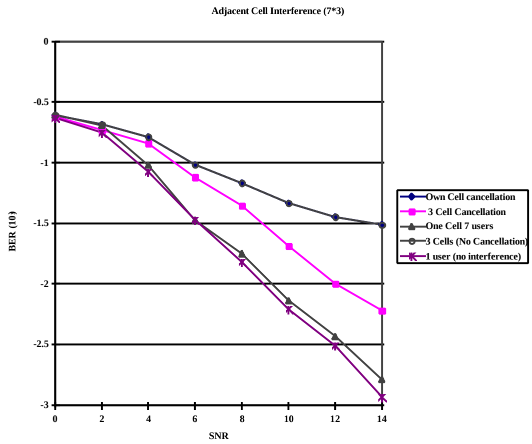
The TDMA has 17 carriers with 3 slots for each of the 16 BSs. Again DCA is more efficient than FCA only up to a limit of 1.5% failing probability, this is not as efficient as FDMA see Figure 5b. For 0.5% the improvement in traffic intensity for DCA with respect to FCA is approximately 0.43, 0.2 and 0.12 Erlang/mile^2 for clusters of 7, 3 and 4 respectively at a failing probability of 0.5%.

This reduction in the efficiency is caused by when a channel is borrowed from an adjacent cell in TDMA three slots are locked, which can not be used by any interfering cells, whereas in FDMA only one carrier is provided.

For PRMA the system consists 16 BSs with 5 carriers with 10 slots each, FCA shows higher traffic intensity for the same failing probability with respect to DCA. DCA techniques where carriers are borrowed from one BS to another do not work well with packet switching multiple access techniques, instead a dynamic slot selection technique is required.

When applying the VCT to CDMA, the BER comparison for a conventional and Parallel Interference Cancellation (PIC) detectors is illustrated in Figure 6a. The curve referred to as ‘1 user (no interference)’ represents a single BS with one user transmitting, and has the best performance obtainable in a given channel.

The introduction of other users and cells creates interference, which reduces the BER curve. ‘3 cell cancellation’ and ‘Own Cell Cancellation’ represent the PIC detector.

a)


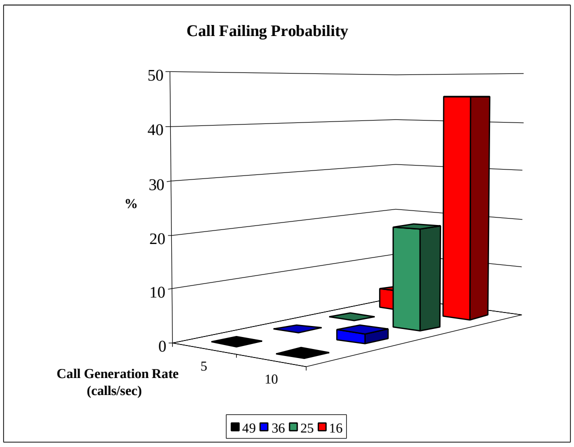
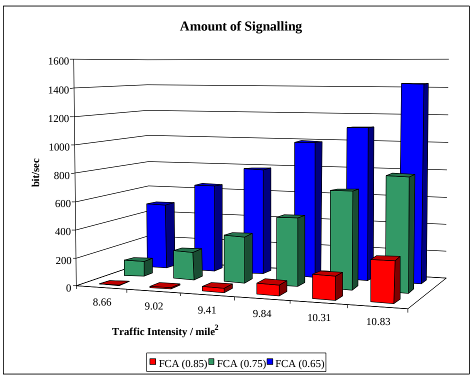
b)


Figure 6 a) BER/SNR Comparison Rician Channel (k = 10 dB) CDMA, b) Failing Probability CDMA

3 Cell Cancellation shows an improvement from 3 Cells (no cancellation), this is due to the information about interfering codes. These improvements in the BER performance can be translated to an increase in capacity, or number of users per cell. If the number of BSs in the area decreases the probability of a call failing increases, see Figure 6b. As would be expected the number of handoffs increase when the cell size is reduced, so a trade off must be made and since the BS can authorise handoff without MSC interference, decreasing the cell size is the more feasible option for increasing the capacity.

The processing at the MSC can be reduced using the call admission control algorithm. A threshold value of traffic is set so that BS perform admission control. The signalling in an FDMA, FCA allocation model with different thresholds has been measured. The number of new connections in a centralised system would be infinite and this signalling may cause congestion problems. Figure 7a) illustrates the signalling that would be employed in a centralised system. In a distributed system, with threshold traffic values this congestion would be avoided at the cost of a higher call failing probability, as shown in Figure 7b).

The call dropping probability with different thresholds is greatly reduced, since some channels are saved for handoffs. Using the threshold method, once a call is accepted it has less chance of failing, but less calls are accepted, the optimum threshold is approximately 0.75.

a)


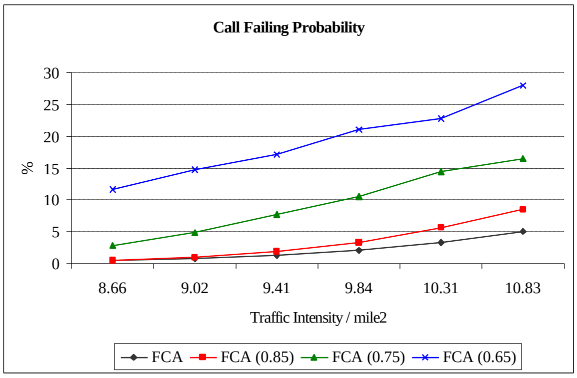
b)


Figure 7 – a) Signalling to Block New Connections (Centralised), b) Threshold Failing Probability

5 Conclusion

Applying the VCT to all the different multiple access methods has proved advantageous, in the reduction signalling traffic. The peak bandwidth of the algorithm varies from 5.76kbits/sec to 26.88kbits/sec this is small considering the rates used in ATM networks (150Mbit/sec). DCA for FDMA provided improvements of 0.87, 0.63 and 0.48 Erlang/mile^2 are shown for cluster sizes of 7, 3 and 4 respectively at a failing probability of 1%. Next was TDMA with 0.43, 0.2 and 0.12 Erlang/mile^2 for clusters of 7, 3 and 4 respectively at a failing probability of 0.5%. In CDMA interference was removed from signals, improving the BER curve. There is more work required for the packet switched applications and IP transport protocols The references [14-16] are a starting point for future work in this area, in which the system will be operated through an IP interface using the ATM technology. For all multiple access methods are more distributed system has been created, for FDMA the signalling saved was shown, this is similar for all the multiple access schemes.

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Alison Heath
MEng, AMIEE
A.L.Heath@staffs.ac.uk

and

Professor Rolando Carrasco
BSc(Hons), PhD, CEng, FIEE
R.A.Carrasco@staffs.ac.uk
http://www.staffs.ac.uk/personal/engineering_and_technology/alh2/

School of Engineering
& Advanced Technology

Staffordshire
UNIVERSITY

EPSRC

CSNDSP
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Contents

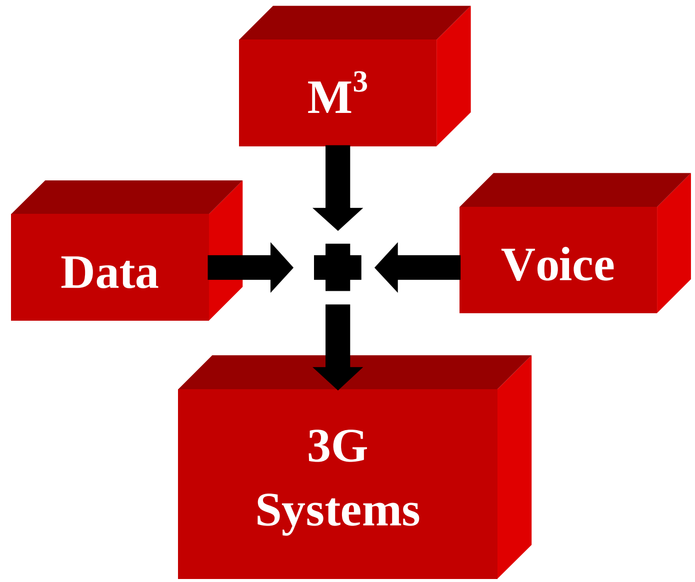
- **Introduction, to 3G communication systems**
- **Background Theory**
  – Multiple Access Techniques, ATM Model
- **VCT Service Adaptable Handoff Algorithm**
- **VCT applied to multiple access techniques**
- **CAC Algorithm**
  – Fixed Channel Allocation/Dynamic Channel Allocation
- **Simulation Model and Results**
  – Signalling BW, Failing Probability for FCA & DCA
  – BER for CDMA when PIC cancellation used
- **Conclusions and Future Work**

Research Objectives

- **Investigate the issues affecting the access to mobile ATM networks**
- **Accommodate mixed types of information**
  - Voice, data, images - Multimedia, and Mobility
- **Reduce the amount of signalling, increase system capacity**
- **Produce a more distributed system**
- **Simplify re-routing of information (handoffs)**

Background

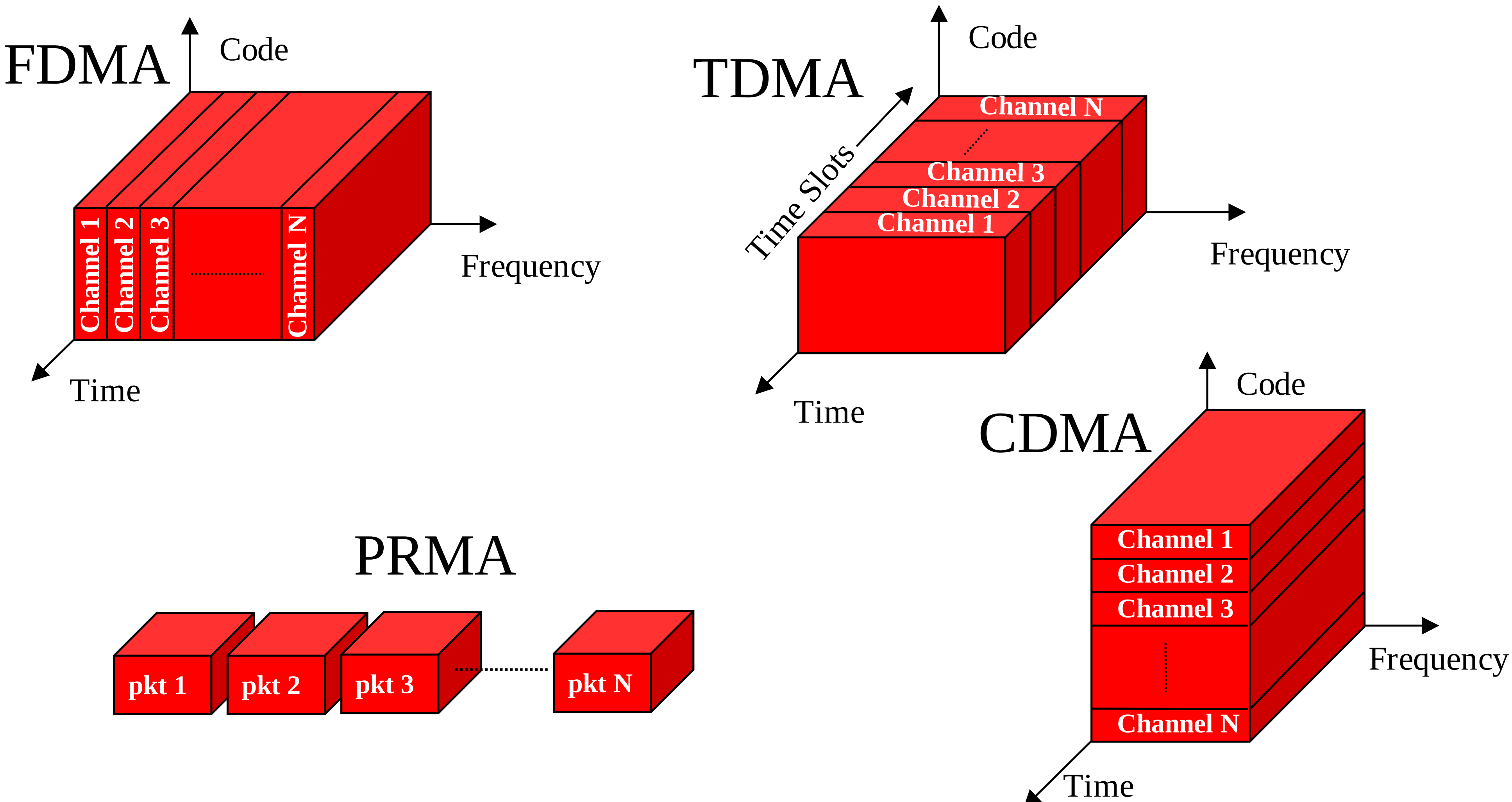
- **Accommodate mixed information types**
  - with different QoS contracts
- **Allow Mobility and high Bit Rates with a finite Band Width**
- **Simplify the routing of information (handoffs)**



IMT-2000/UMTS

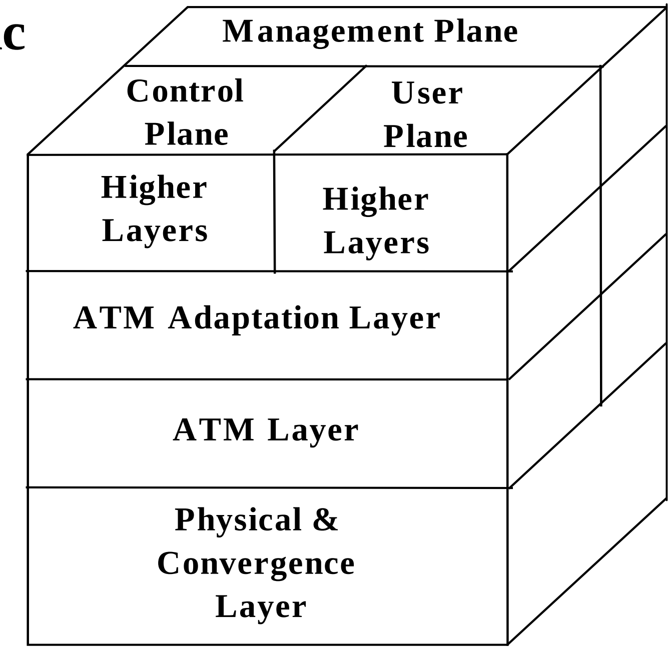
cdma2000 WCDMA

Multiple Access Techniques



Asynchronous Transfer Mode (ATM)

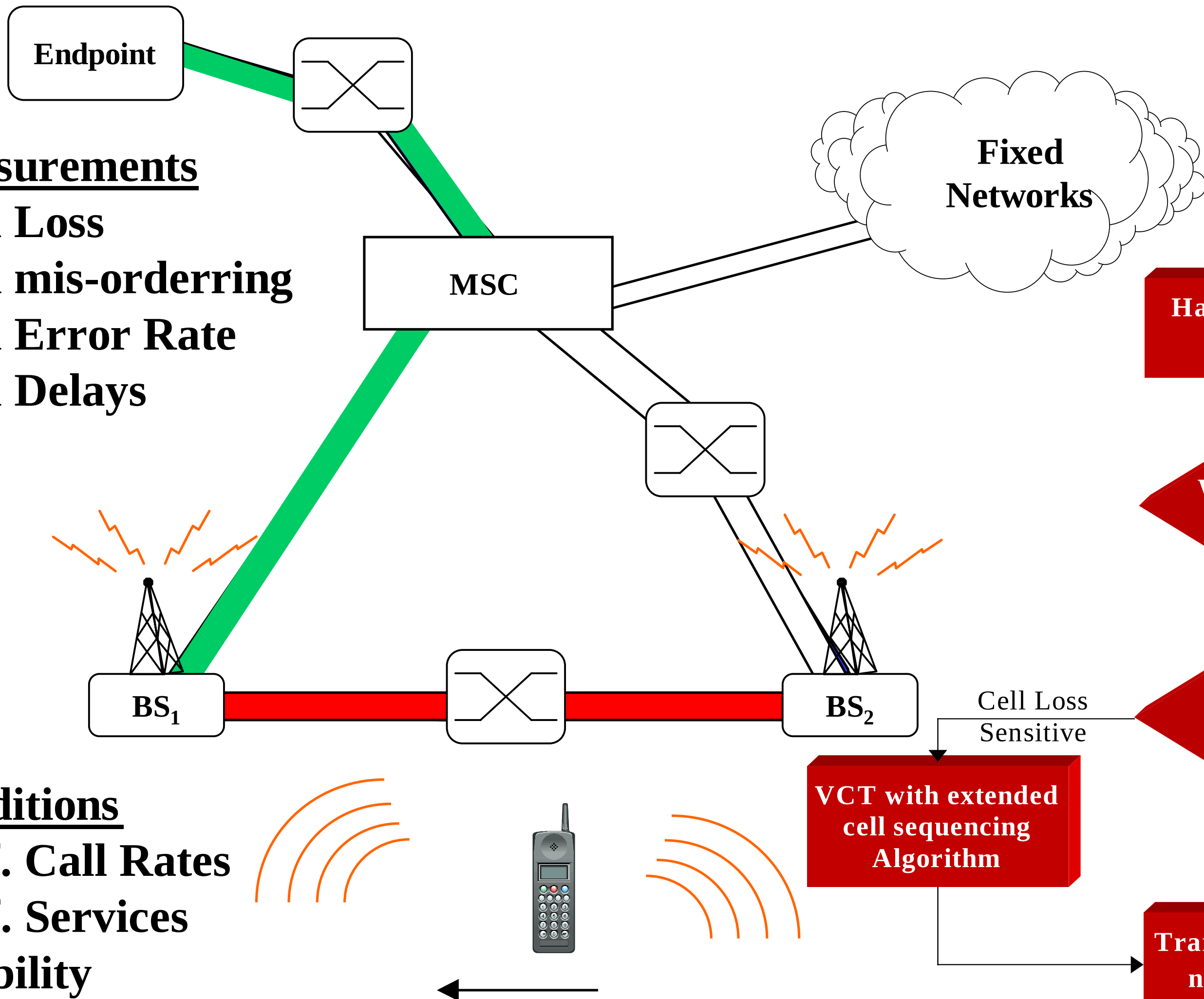
- **Different types of services at different traffic rates using the same unique Universal Network**
- **Common Network Layer for all types of traffic**
- **Intelligent Network that assures QoS**
- **UMTS and Wireless ATM (Mobile)**



ATM Protocol Reference Model

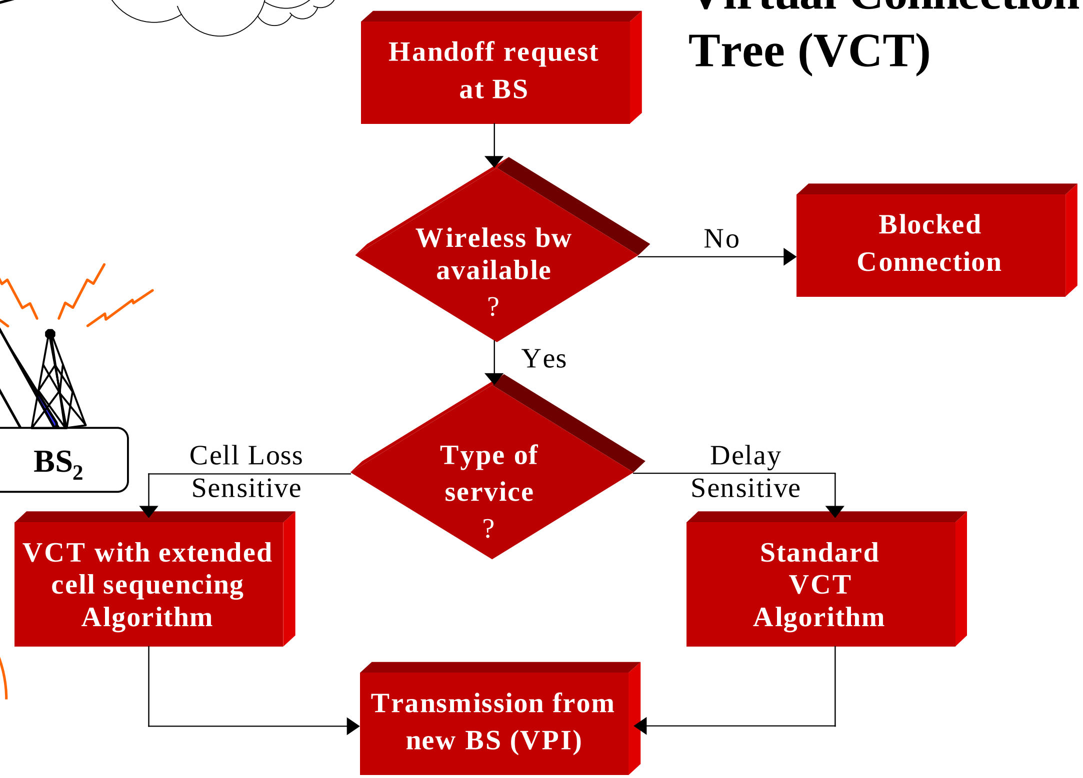
Service Adaptable Handoff Algorithm

Measurements
- Cell Loss
- Cell mis-orderring
- Cell Error Rate
- Cell Delays



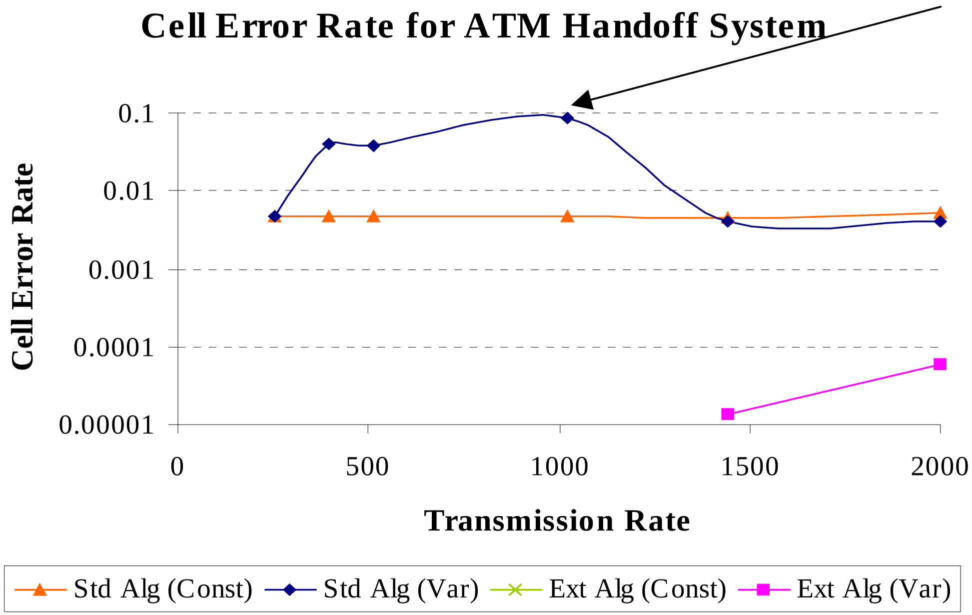
Conditions
- Diff. Call Rates
- Diff. Services
- Mobility

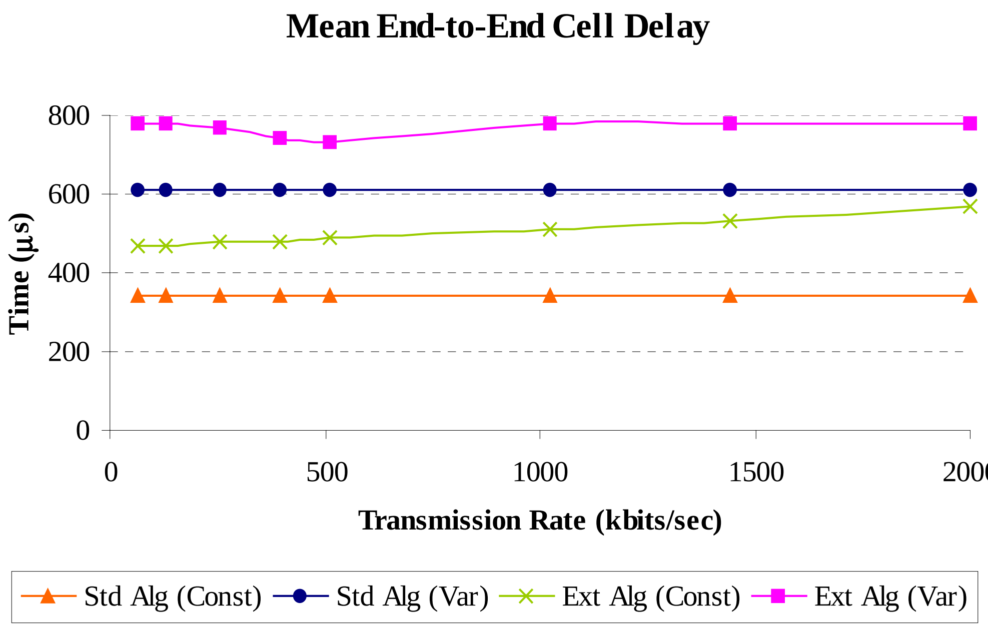
Objectives
- Test Algorithm Performance
- Compare to Simple Virtual Connection Tree (VCT)



Cell Error Rate & Mean End-to-End Cell Delay

Higher CER, bursty sources max = 0.085



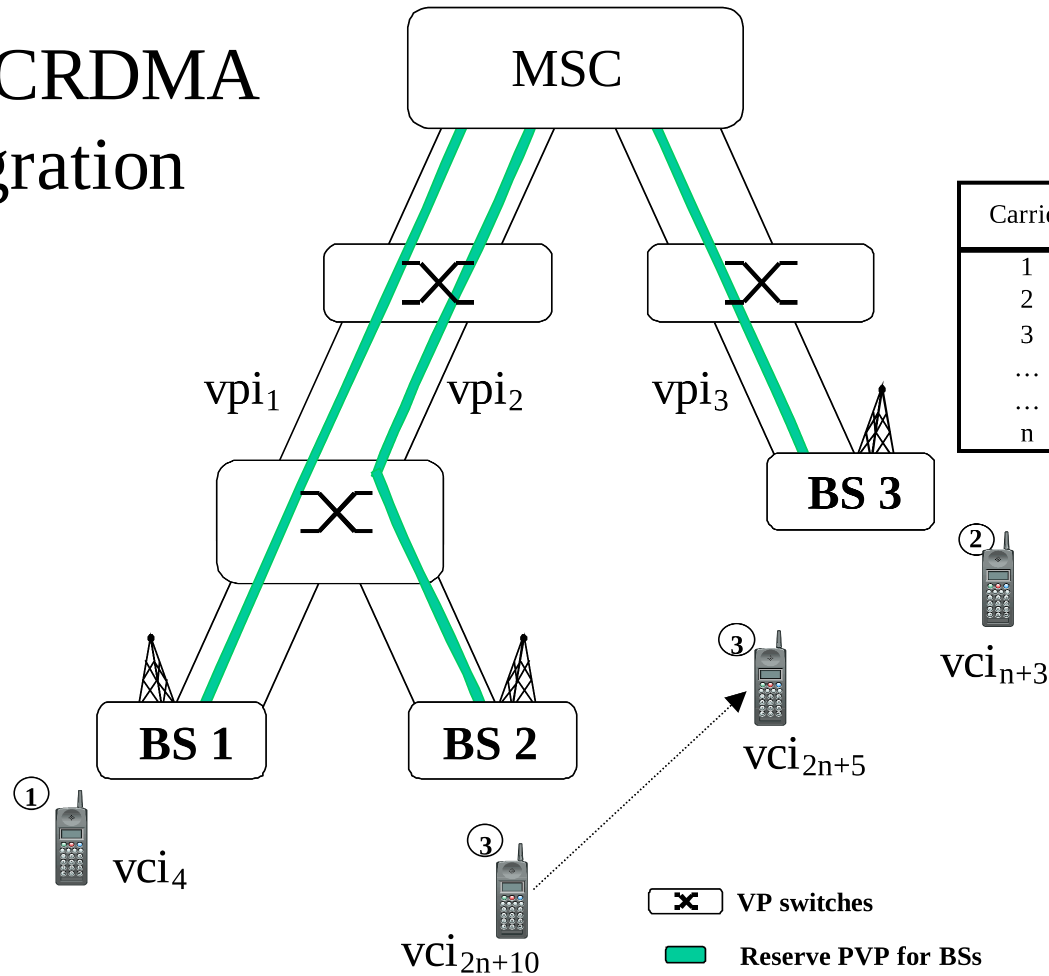


$$CER = \frac{no.of\ \ lost\ cells + no.of\ \ sequencing\ errors}{no.of\ \ cells\ transmitted}$$

Variable traffic larger mean delay than constant traffic

VCT applied to multiple access techniques

VCT - CRDMA Integration



MS	VPI	VCI	
1	1	4	
2	3	n+3	
3	2	2n+10	before h/o
3	3	2n+5	after h/o

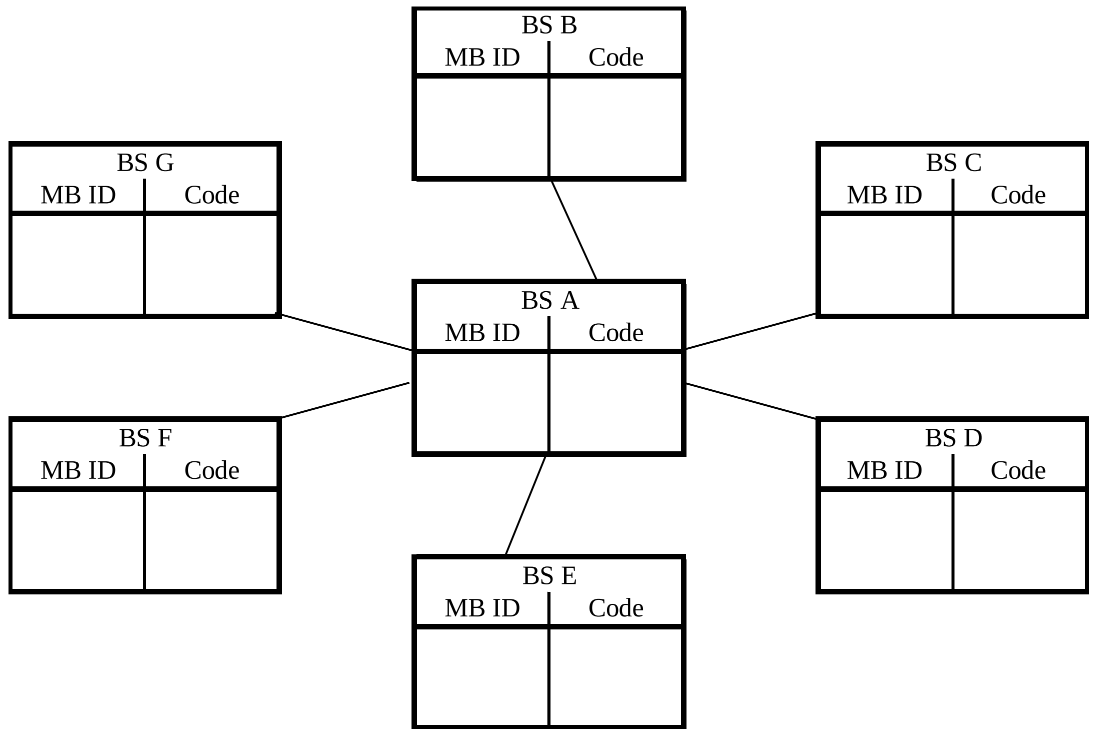
Carrier	VCI				
	MS 1	MS 2	MS 3	…	MS m
1	1	n+1	2n+1	…	(m-1)n+1
2	2	n+2	2n+2	…	(m-1)n+2
3	3	n+3	2n+3	…	(m-1)n+3
…				…	
…				…	
n	n	2n	3n	…	m n

Carrier Communication (CAC) Algorithm

- **Passing in real time information gathered at MSC to all BSs in VCT.**

Size of MAP

$$S = (B_i + 1)C$$

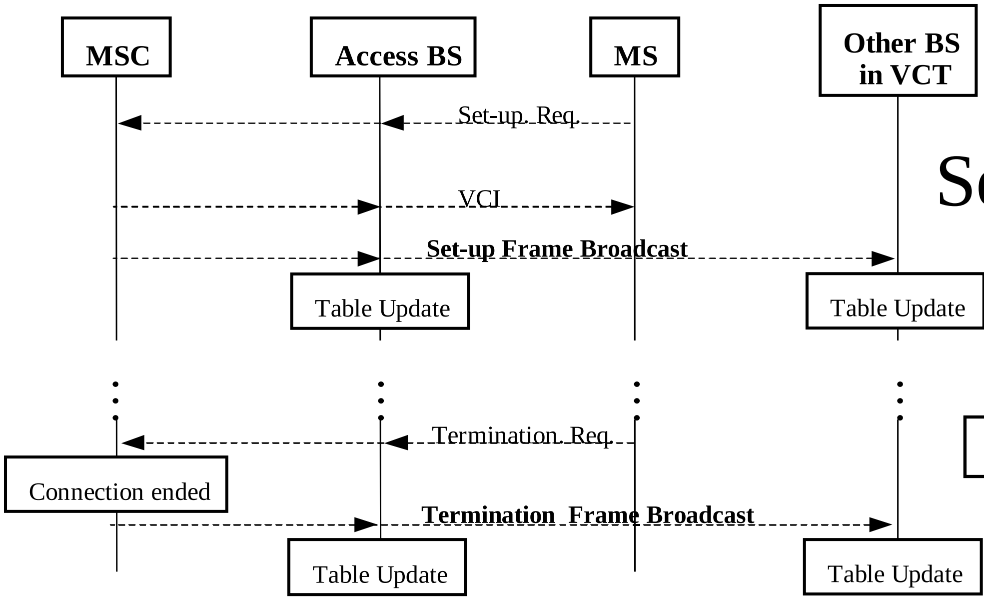


MAP at BS A

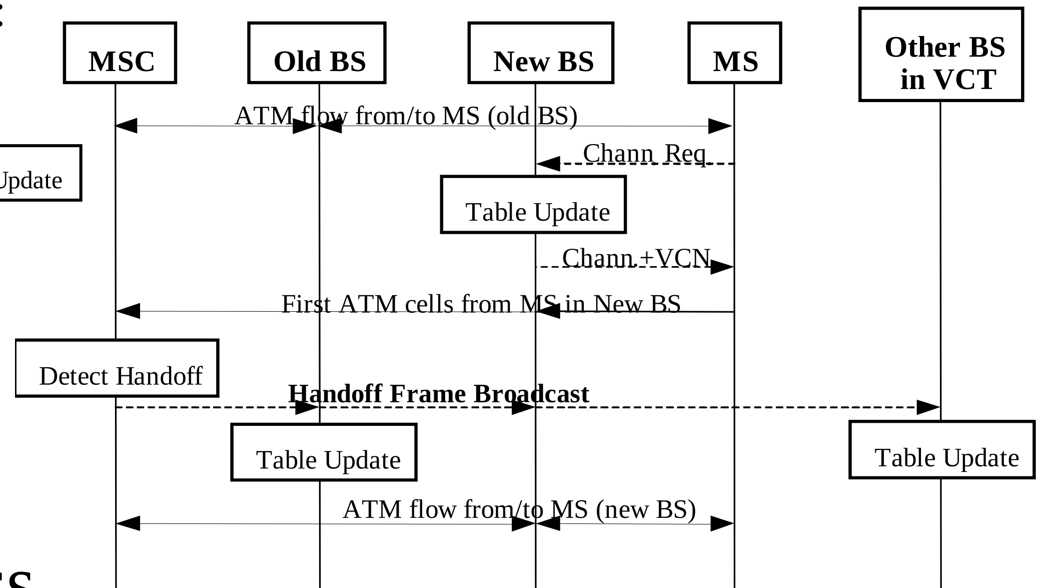
Active User Table

REF	MB ID	……	Service Type	Rate
		…… ……		

CAC Algorithm Processes



Set-up & Termination Process



Handoff Process

CAC Frames

- Allows 2^{15}(32768) users, 2^{9}(512) BSs and 2^{11}(2048) Carriers

Set up Frame

MB ID Number	Ref. Number	New BS	Carrier	……	Service	Rate
?? bits	15 bits	9 bits	11 bits		n bits	

Handoff Frame

Ref. Number	New BS	New Carrier
15 bits	9 bits	11 bits

Termination Frame

Ref. Number
15 bits

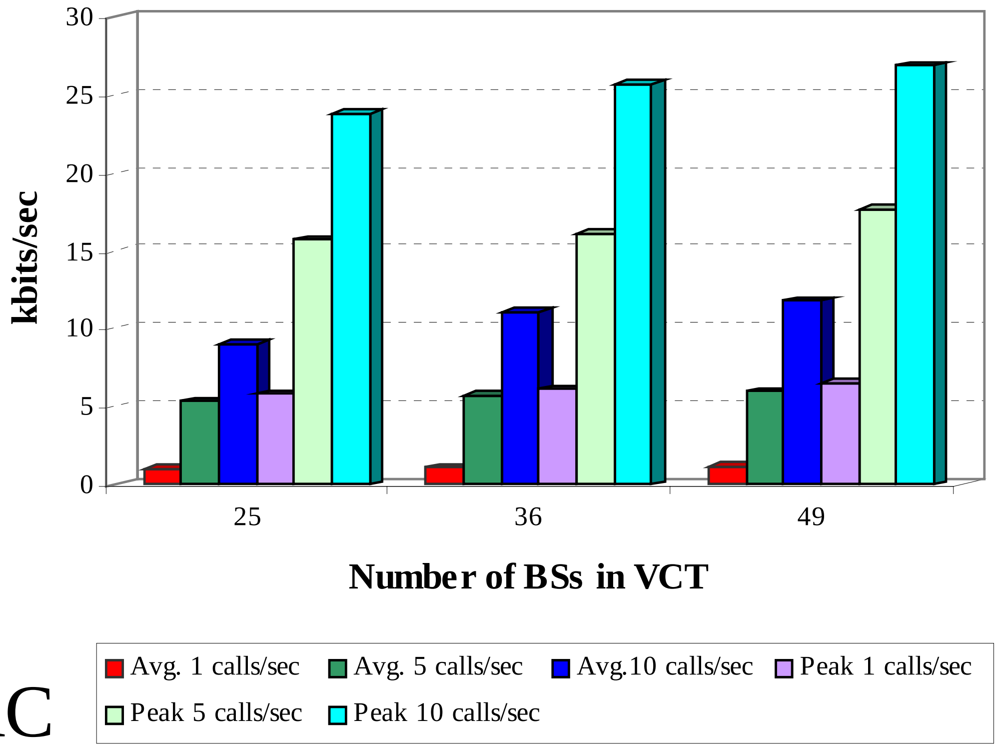
- Allows DCA schemes
- System becomes distributed

Simulation Model

- **Band Width and Signalling in fixed network for CAC Algorithm**
- **Comparison between FCA & DCA for TDMA, FDMA and PRMA**
- **CAC at BS level**

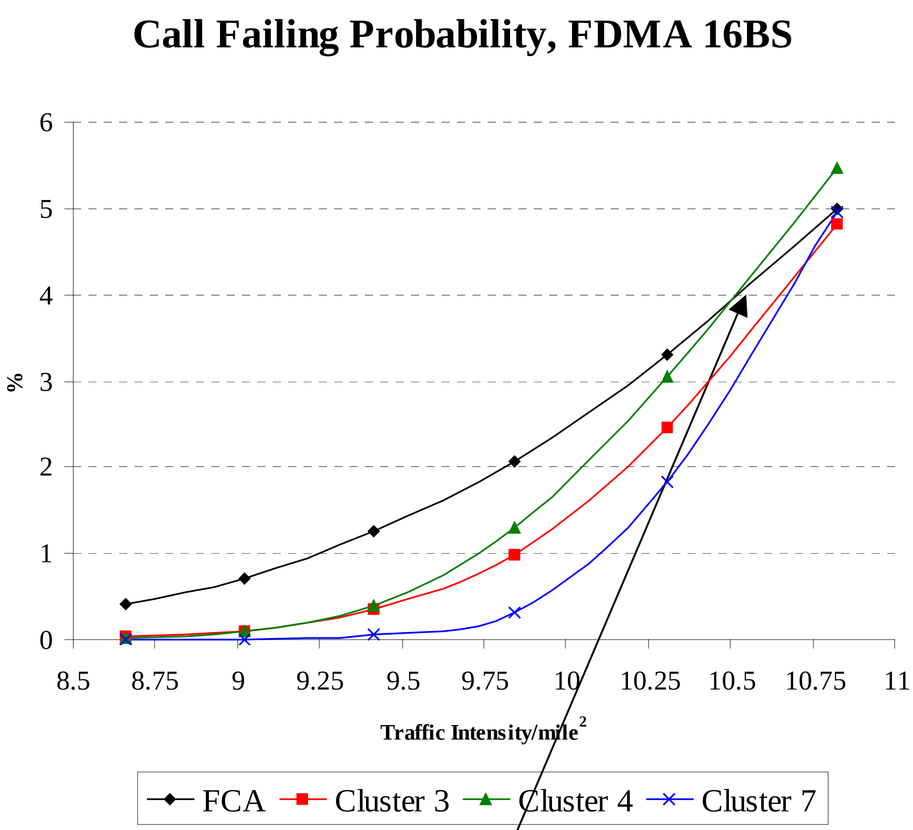
Area (M)	77.94 miles2
No. of BS	16
Call gen rate (avg, μ)	1, 5, 10 call/sec
Simulation Duration	500 3600 sec
Channels per BS	50
Cluster sizes	3, 4 and 7
No. channels and slots	FDMA 50; 1
	TDMA 17; 3
	PRMA 5; 10
Speed	20 - 70 miles/h
Length	30 - 240 sec.
Directions (max)	8

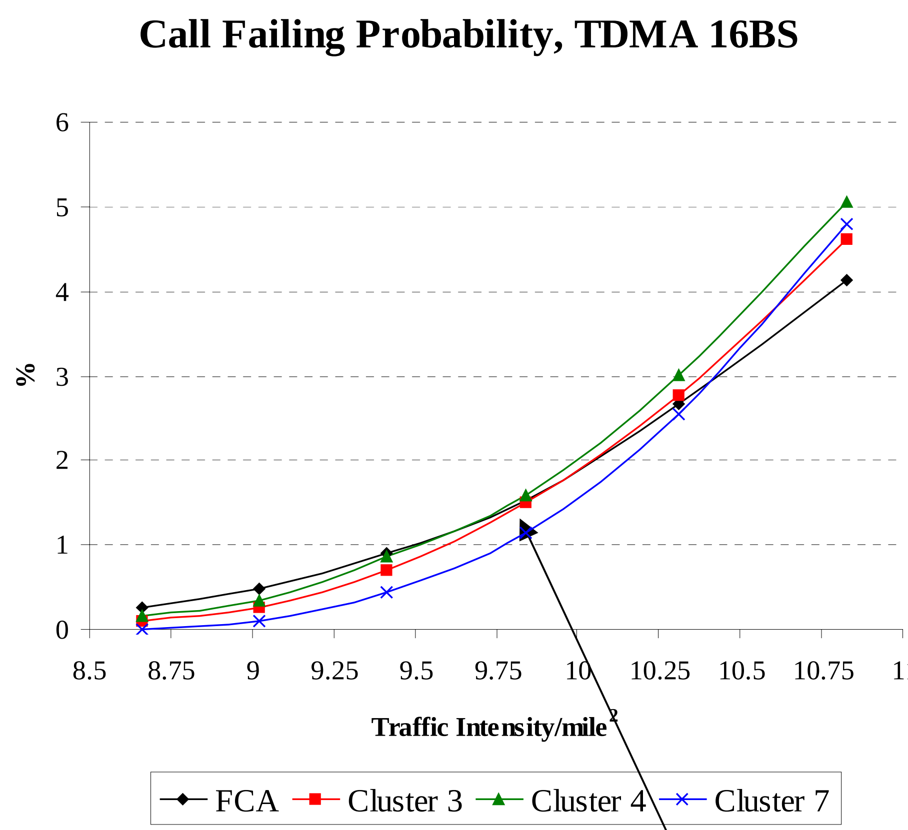
Bandwidth



BW Saved with CAC

Call Failing Probability, FDMA & TDMA



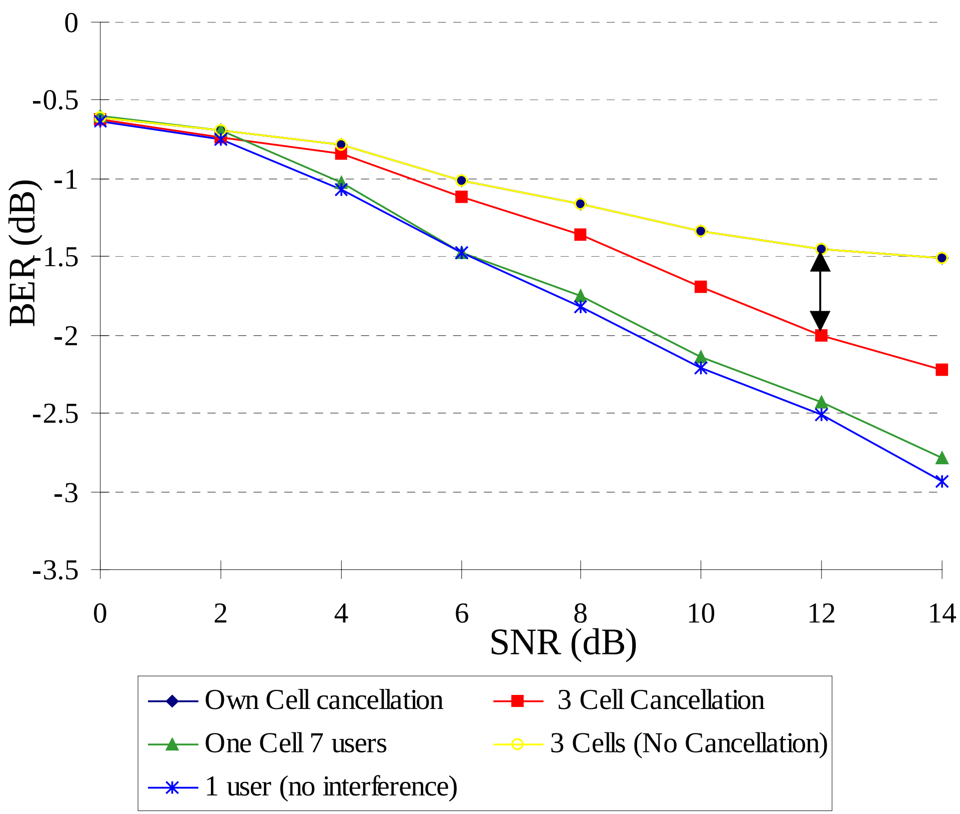


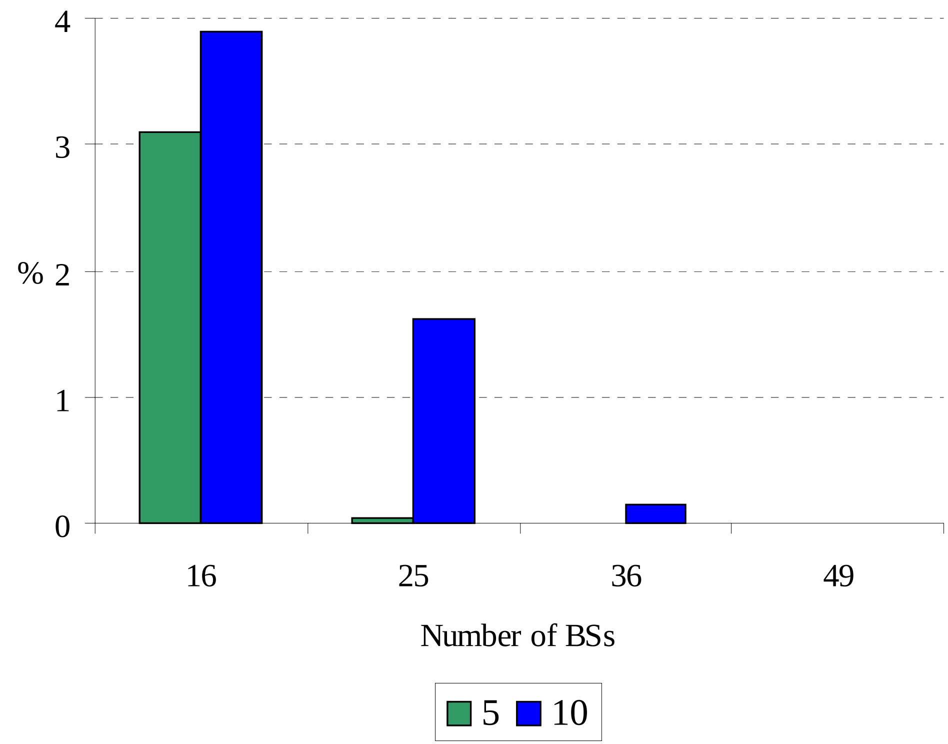
DCA allows higher traffic intensity of traffic than FCA until 4%

FDMA more efficient than TDMA

DCA more efficient than FCA up to 15%

CDMA



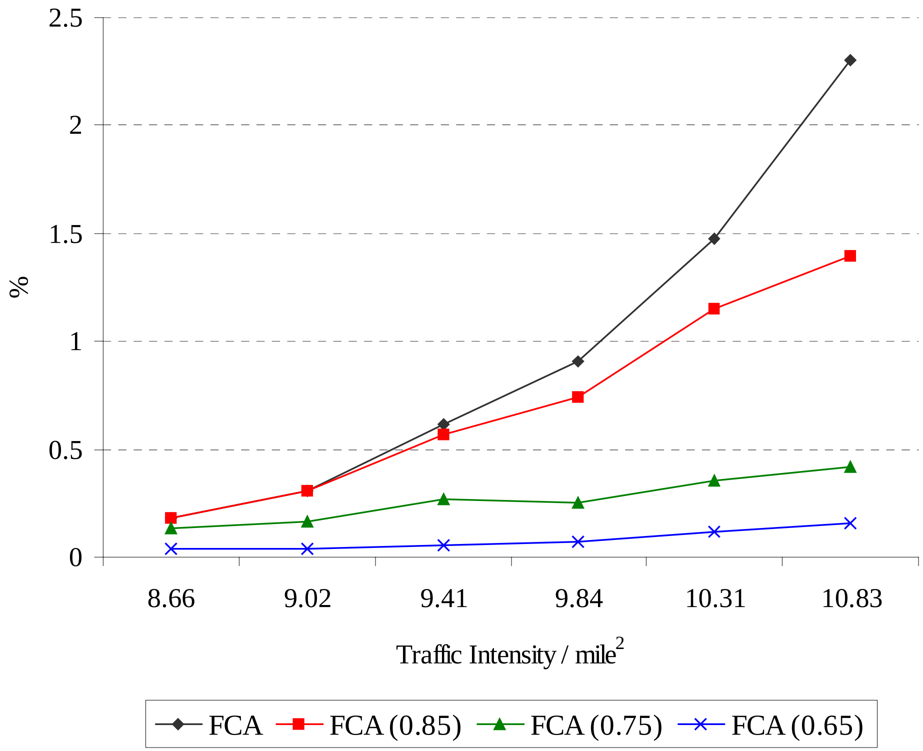


With cancellation gives >0.5db improvement at SNR of 12dB

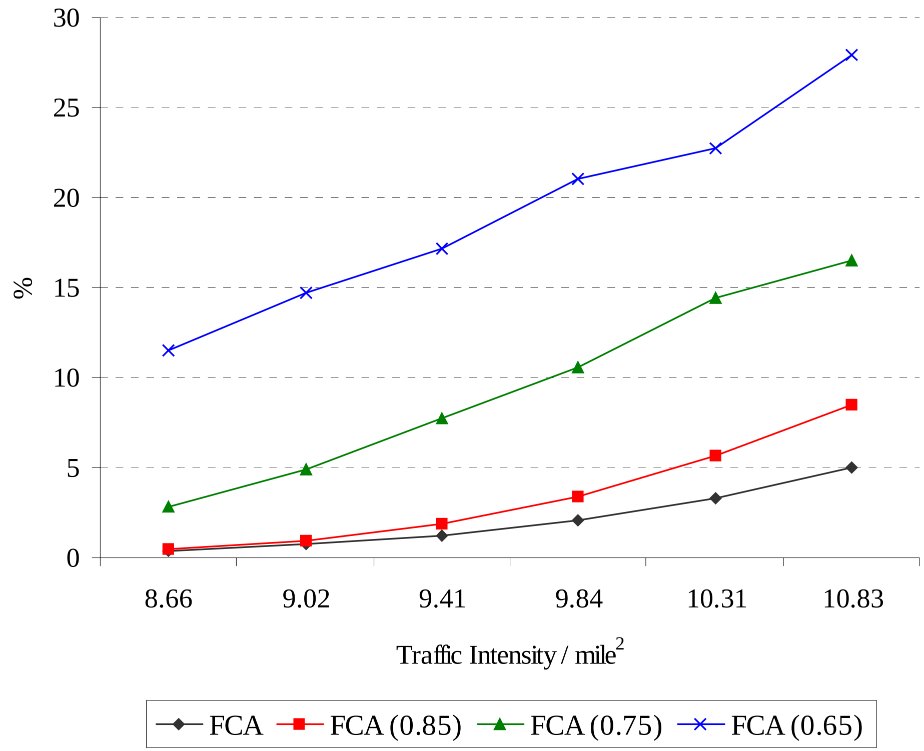
As the number of BSs increase the probability of a call failing decreases

FCA FDMA

Call Dropping Probability



Call Failing Probability

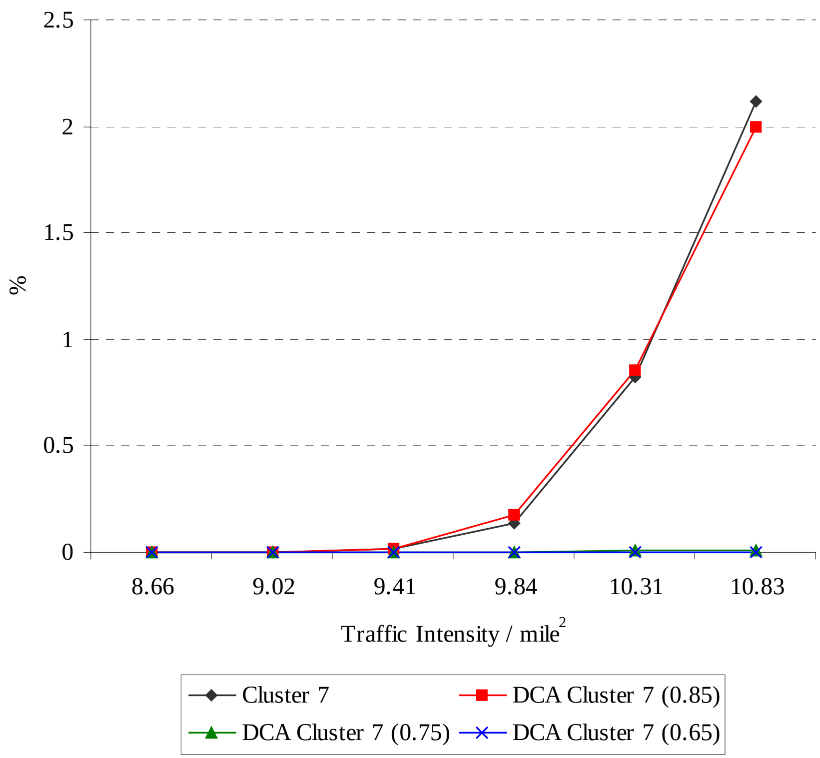


Call dropping probability increases as threshold is reduced

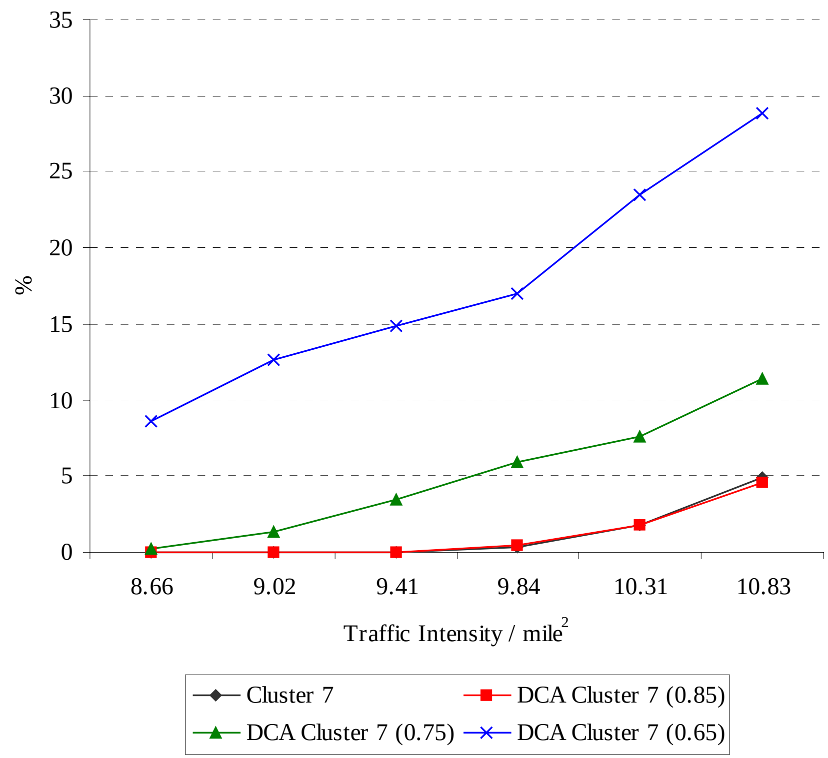
Probability of a call failing is dramatically reduced as the threshold is increased. (Optimal threshold of 0.15)

DCA FDMA

Call Dropping Probability (DCA)



Call Failing Probability (DCA)

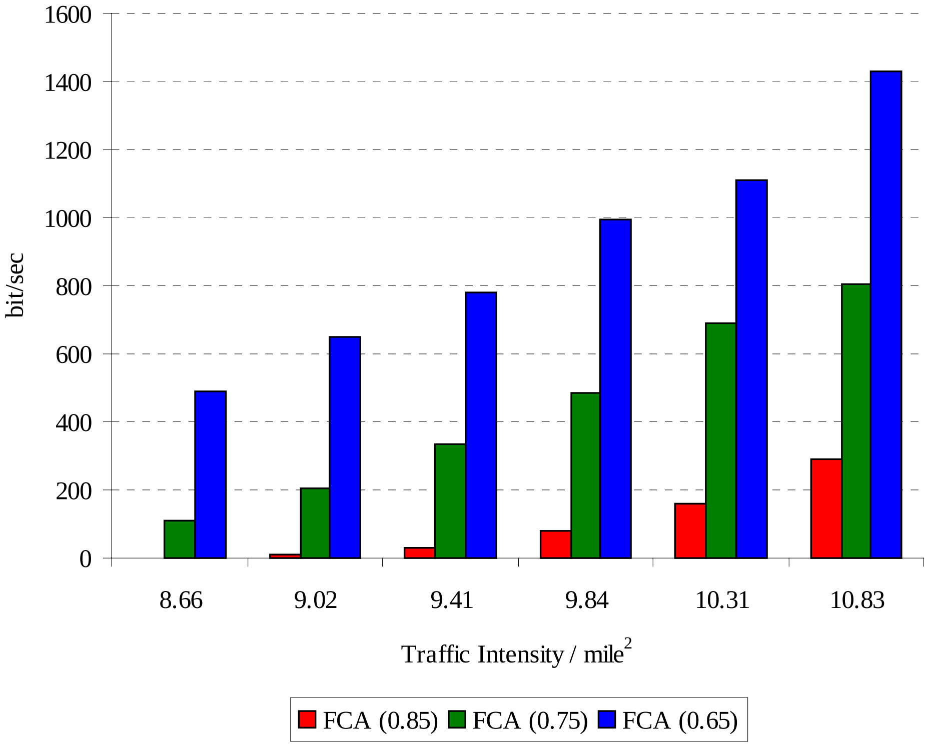


- Call dropping probability reduces to very small value at thresholds of 0.25, 0.35 for DCA

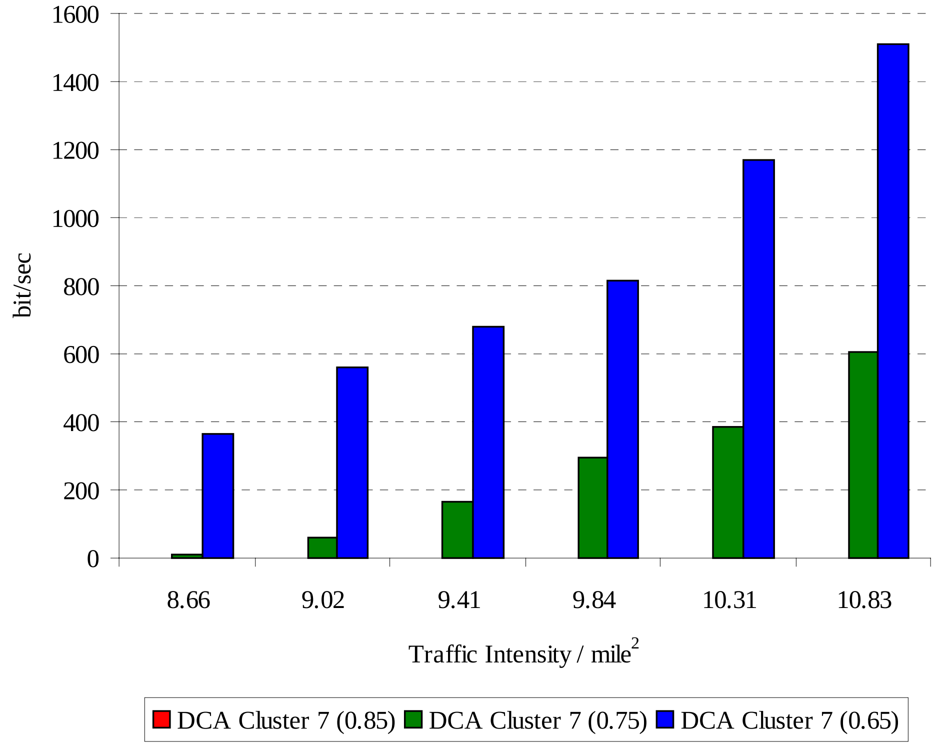
- Call failing probability less for DCA than FCA.
- Optimal threshold value of 0.15

Signalling Saved

Amount of Signalling (FCA)



Amount of Signalling (DCA cluster 7)



The amount of signalling saved increases with traffic intensity and with a reduction of threshold, which reduces the processing at the MSC

Conclusions

- Applying the VCT to all the different multiple access methods has proved advantageous, in the reduction signalling traffic.
- The peak bandwidth of the algorithm varies from 5.76kbits/sec to 26.88kbits/sec this is small considering the rates used in ATM networks (150Mbit/sec).
- DCA for FDMA provided improvements of 0.87, 0.63 and 0.48 Erlang/mile^2 are shown for cluster sizes of 7, 3 and 4 respectively at a failing probability of 1%. Next was TDMA with 0.43, 0.2 and 0.12 Erlang/mile^2 for clusters of 7, 3 and 4 respectively at a failing probability of 0.5%.
- In CDMA interference was removed from signals, improving the BER curve.
- There is more work required for the packet switched applications and IP transport protocols
- For all multiple access methods are more distributed system has been created, for FDMA the signalling saved for FCA & DCA was illustrated, this is similar for all the multiple access schemes.

Future Work

- Investigate reasons for cell sequence errors at high speeds
- Implement similar Algorithm for TCP
- Implement a packet switched B-ISDN system to run on top of IP
- Investigate multiple access schemes such as cdma2000, WCDMA, TDMA, FDMA