

Providing Voice Connectivity to Rural India: Issues and Solutions

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Agenda

- Introduction
- Background and Motivation
- Rural Kiosk Model
- WiMAX
- Dynamic Frame Profile Algorithm
- Performance of DFP Algorithm
- Conclusion
- Future Work
- References



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Introduction

- Emerging Markets like India Undergoing Tremendous Telecommunication Expansion and Growth
- A few Facts About Indian Telecom Scenario
 - 149.75 Million Telephone Subscribers as of March 2006
 - 49.75 Million Fixed Wire line Telephone Subscribers
 - Mobile Subscribers Growing at a Faster Rate than the Fixed Telephone Subscriber
 - Cost of Deployment of Fixed Mobile Telephone is USD \$600
 - Cost of Deployment of Mobile Telephone is USD \$100



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Background

- Geographical Area of India Divided in 4 Tiers

Type of Region	Description
Tier 1	Large Cities of India
Tier 2	Major Cities in India
Tier 3	Sub-urban areas in India
Tier 4	Village in India

- Majority of Growth Rate Projected to Come from Tier-2 and Tier-3 Regions



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Background Cont'd

- **Characteristics of Tier-2 and Tier-3 Regions**
 - **Low Literacy**
 - **Limited Revenue Earnings for Broadband Internet Access**
 - **Major Revenue Projected to Come from Voice Connectivity**
 - **Low Income**
 - **Tier-2 income USD\$245**
 - **Tier-3 income USD\$109**
 - **Providing Low Cost Telecom Service a Challenge**
 - **PC Penetration**
 - **Increasing PC Penetration**
 - **VoIP Projected to Be the Next Killer Application**



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Background...cont'd

- **Rural India**
 - **Difficult Geographical and Terrain Condition**
 - **Not Conducive for Laying Optical and Fiber Cable**
 - **Deployment of Fixed Wireline Solutions Expensive**
- **Solutions for Providing Voice Connectivity to Rural India**
 - **Public Call Office (PCO)**
 - **Small Kiosks**
 - **Cost Effective**



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Options Available

- **Wireless Backhaul and Access Networks**
 - 802.11 in mesh mode
 - Optic to the Kerb and wireless to the last mile
 - 802.16x as the backhaul and wireless as the last mile
- **Proposal**
 - A Kiosk Based WiMAX Infrastructural Model for Rural Voice Connectivity
 - A Dynamic Frame Profile Algorithm for Enhancement of VoIP Capacity for WiMAX Based Network
 - Use of VoIP Solutions for End-user

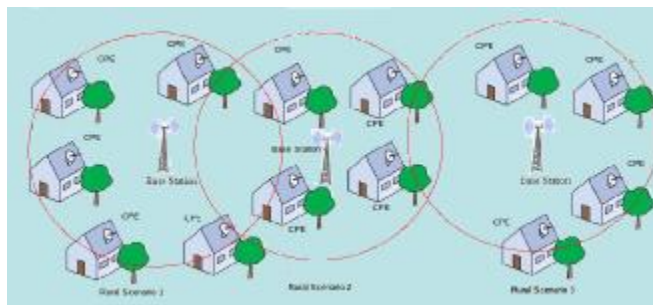


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Rural Kiosk Model



A Typical Rural Scenario

- A WiMAX Base Station Covering 2-3 Villages Comprising of Few Hundreds to Thousand Households



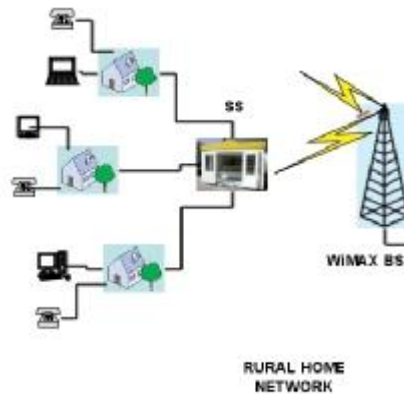
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Rural Kiosk Model

- Provides Affordable POTS Connectivity
- Cost Effective Deployment for the Service Provider
- Kiosk is a WiMAX Subscriber Station
- Each WiMAX BS Sector Serves a Village



Proposed Kiosk Model For Rural Voice Connectivity



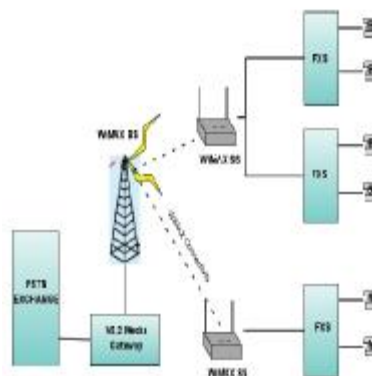
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Rural Kiosk Model

- Foreign Exchange Subscriber (FXS)
 - POTS serviced by SS terminated at FXS
 - Converts DTMF Signalling to VoIP Call using SIP
 - Consists of An Enum Server and SS7 Stack
- Enum Server
 - Converts PSTN number to An Equivalent SIP Address
- Media Gateway
 - Based on Media Gateway Control Protocol (MGCP)
 - Provides Signaling Support and Interface With PSTN Network



The Proposed Rural Telecom Architecture

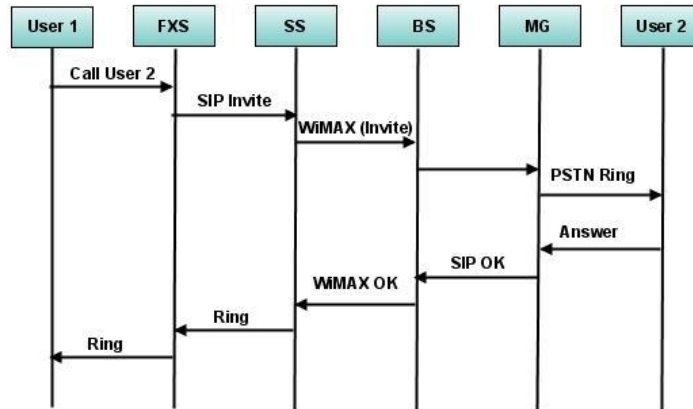


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Rural Kiosk Model



A Typical Call Flow Diagram for the Proposed Architecture



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Why Multiple VoIP Connections cannot be supported over a Single Subscriber Station?

VoIP Performance Analysis over 802.16e

No. of SS	Scenario I		Scenario I		Scenario II	
	Delay	Jitter	Delay	Jitter	Delay	Jitter
2	124ms	2.7ms	124ms	2.3ms	120ms	08ms
4	287ms	1.2ms	706ms	1.2ms	340ms	1.07ms
8	283ms	1.7ms	18.5ms	2.4ms	14.2ms	2.1ms

The VoIP applications require a maximum Delay of 120 msec and maximum delay jitter of 50 msec. From the performance results of VoIP from the table above

ØThe delay for 2 subscriber stations (which is the requirement for rural scenario) is above the tolerable limit.

ØDetailed results (refer to the attached document) indicate a high delay and delay jitter for high connection densities

REASONS

- Unfair Scheduling Algorithm (Weighted Round Robin used)
- Packets have to wait a longer time for transmission due to limited frame length.
- Not enough transmission opportunity available in a single frame.

Problem Statement

- What is the mechanism to minimize the number of required Subscriber stations for a given user density and maximize the number of simultaneous VoIP calls for UGS and rtPS supported over the subscriber station without affecting the QoS of admitted calls
- How to improve QoS at high loads per SS



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Rural Kiosk Model

- **Cost Analysis**
 - Service Provider to Invest in Kiosk
 - Cost of Kiosk 24 Port FXS, Subscriber Station and Wiring Cost Approximately USD\$3000
 - WiMAX Base Station is Provided by Primary Service Provider, Approximately USD\$30000
 - End User Just invests in POTS Instrument Costing USD \$5
- Service Provider Can Recover Investment Cost in 2 Years



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WiMAX

- Defines 2 Service Classes to Support Voice Services
 - Unsolicited Grant Service (UGS)
 - Extended Real-Time Polling Service (ertPS)
- By Dynamically Varying Frame Length Capacity of The Network Can Be Enhanced
- The 802.16x Standard Provides a Framework for Changing Frame Length

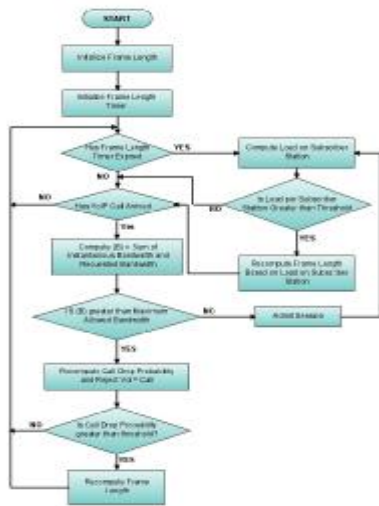


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Details of the Proposed Algorithm



- The Base station (BS) operation with a default frame size
- BS sends the DL-MAP and UL-MAP sub-frames with the downlink data
- On receiving the uplink data the BS analyzes the data for requests for new connections
- BS performs call admission control on the connection requests
- If the call is admitted
 - BS computes the load per subscriber station
 - BS verifies whether the current frame length is enough to meet the QoS requirement of all admitted calls
 - If not the BS computes the new frame length (As per the algorithm in the attached document (Sec.))
 - The base station resumes operation with the new frame length
- If the call is dropped
 - BS computes the call drop probability
 - BS verifies whether the call drop probability is within the threshold value
 - If not BS computes the new frame length
 - The base station resumes operation with the new frame length



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Simulation Scenario

- VoIP Codec G.729
 - Payload Size 20 Bytes
 - Data Rate 8Kbps
- Call Duration is Poisson Distributed With a Mean of 16 Seconds
- Inter-Arrival Time Between Calls is Exponentially Distributed With a Mean of 0.1 Seconds
- 1 Base Station with 8 Subscriber Station
- A Maximum of 64 Connections Allowed to Exist During the Simulation
- Simulation Scenario
 - Scenario 1: Only UGS Connections Exist
 - Scenario 2: Only ertPS Connections Exist
 - Scenario 3: Mixture of UGS + ertPS Connections Exist

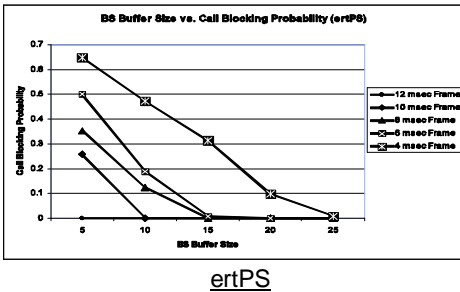
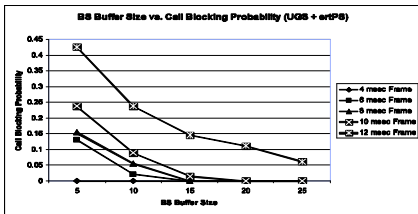


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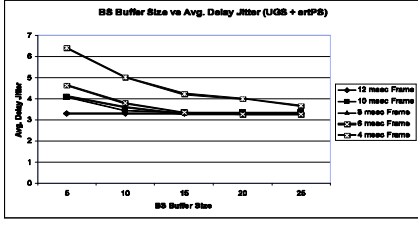
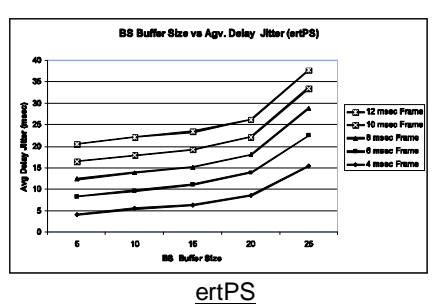
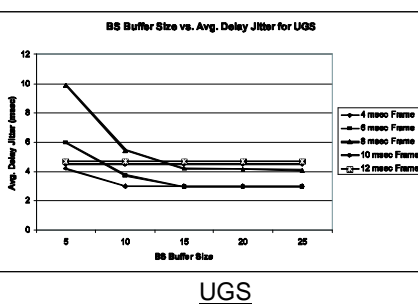
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Performance of DFP Algorithm



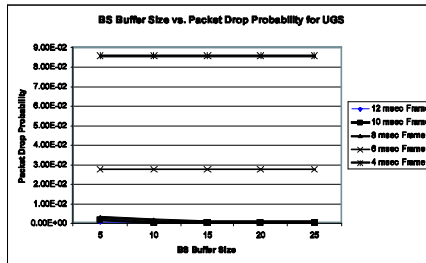
- The Plots Show the Variation of Call Blocking Probability With Varying Frame Length and Base Station Buffer Size
- Call Blocking Probability with Varying BS Queue Size
- Call Blocking Probability Falls as Frame Size Increases

Performance of DFP Algorithm

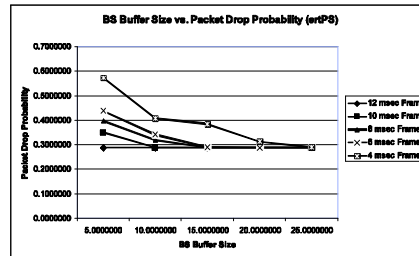


- The Plots Show the Variation of Delay Jitter With Varying Frame Length and Base Station Buffer Size
- Delay Jitter Well Within the Maximum Threshold Limit of 50 Milliseconds
- Delay Jitter Decreases With Increase in Frame Length

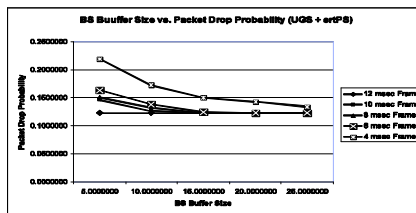
Performance of DFP Algorithm



UGS



ertPS



Mixed

- The Plots Show the Variation of Packet Loss Ratio With Varying Frame Length and Base Station Buffer Size
- Packet Loss Ratio with Varying BS Queue Size
- Packet Loss Ratio Falls as Frame Size Increases



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Conclusion

- Cost-Effective Rural Kiosk Model
- Low Cost Solution for Providing Voice Connectivity
- Dynamic Frame Profile Algorithm Successfully Enhances the Capacity of the Network
- Economic Sustainability of the Technology Improved
- Optimization Required Between Base Station Buffer Size and Frame Length



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Future Work

- There are Synchronization issues in the current proposal which need to be addressed.
- How does the proposed solution scale?
- More detail investigation required to arrive at more comprehensive figures/results.
- Mobility support?
- Is WiMAX as backhaul and Wi-Fi as last mile more cost effective? Performance?



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Addition Work at Motorola Research Labs

- Rural Broadband MAC
- Cluster Connect (Wi-Fi Mesh for Rural Connectivity)
- MotoPost (Delay Tolerant Network)



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Background..A VoIP perspective

Traffic Classes In WiMAX

QoS Category	Applications	QoS Specifications
UGS Unsolicited Grant Service	VoIP	<ul style="list-style-type: none"> • Minimum Sustained Rate • Maximum Latency Tolerance • Jitter Tolerance
rtPS Real-Time Polling Service	Streaming Audio or Video	<ul style="list-style-type: none"> • Minimum Reserved Rate • Maximum Sustained Rate • Maximum Latency Tolerance • Traffic Priority
ertPS Enhanced Real-Time Polling Service	Voice with Activity Detection (VoIP)	<ul style="list-style-type: none"> • Minimum Reserved Rate • Maximum Sustained Rate • Maximum Latency Tolerance • Jitter Tolerance • Traffic Priority
nrtPS Non-Real-Time Polling Service	File Transfer Protocol (FTP)	<ul style="list-style-type: none"> • Minimum Reserved Rate • Maximum Sustained Rate • Traffic Priority
BE Best-Effort Service	Data Transfer, Web Browsing, etc.	<ul style="list-style-type: none"> • Maximum Sustained Rate • Traffic Priority

- WiMAX is based on 802.16 standard. Some of the salient features of WiMAX are
 - Supports a range of about 30 miles
 - Supports data rate in excess of 70mbps for fixed broadband and 20/30 mbps for mobile broadband
 - Operates in frequency range of 2-11 Ghz.
 - Provides inbuilt support for Quality of Service.
- WiMAX defines five traffic classes (UGS,rtPS,ertPS,nrtPS and BE) as shown in table.
 - Out of these five classes two classes are used for VoIP
 - Unsolicited Grant Service (UGS)
 - Enhanced Real-Time Polling Service (ertPS)
- WiMAX infrastructure comprises a Base Station (BS) and a set of Subscriber Stations (SS) which are bound to a base station.
 - The SS basically form the customer premise equipment and multiple devices can be connected to the SS.
 - In the present disclosure we assume that the devices connected to the SS are only VoIP enabled devices.



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Proposed Solution

Proposed Solution

In this disclosure a method in the form of an algorithm and an apparatus in the form of an architecture with an instantiation at the Base station is proposed to dynamically vary the frame size. The variation in the frame size is based on

- Call Drop Probability
- Effective load at the Subscriber Station

Advantages

- Increase in network capacity.
- Increase in the number of simultaneous VoIP calls supported over a single subscriber station

Fundamentals of Proposed Solution

The base station maintains a state information related to the allocated bandwidth and load per SS.

When a new VoIP call arrives, based on the Instantaneous allocated bandwidth and requested bandwidth a decision is taken to whether admit the call.

In case the incoming call is rejected, the dynamic frame profile algorithm determines a new frame duration.

In case the incoming call is admitted determine whether the load per SS is within threshold values.

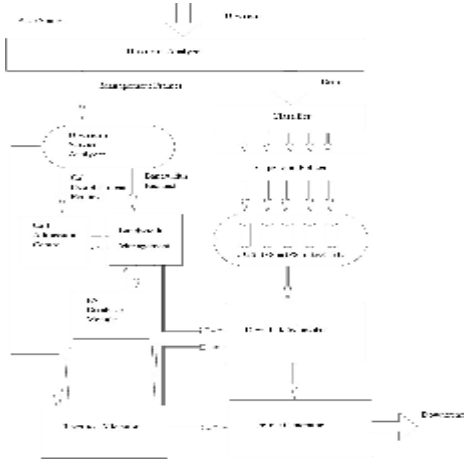
In case the load per SS is greater than threshold determine the new frame length.



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Details of the Proposed Apparatus (Enhanced Architecture at Base Station)



- **Upstream Analyzer** – Differentiates between the management frames and data frames
- **Classifier** – Analyzes the data frames and maps them to different service flows such as UGS,rtPS,ertPS, and BE
- **Shaper and Policer** – Performs flow control
- **Downlink Scheduler** – Based on the negotiated QoS determines the downlink schedule.
- **Upstream Service Analyzer** – Differentiates the management frame as call admission requests, bandwidth request, Uplink resource allocation requests and sends them to the required blocks for servicing
- **Call Admission Control** – Based on the requested QoS, determines whether new session can be admitted or not
- **Bandwidth Management** – Determines the bandwidth to be allocated for downlink and uplink and their distribution among the contending SS
- **BS Database Module** – Stores information regarding the admitted calls and their QoS requirements. Keeps track of the number of rejected calls and load per SS
- **Resource Allocator** – Determines on call rejection or admission whether the current frame length is enough to meet the QoS requirement of the active calls. The new frame length is communicated using UL-MAP.
- **Frame Generator** – Creates/modifies the new frame.

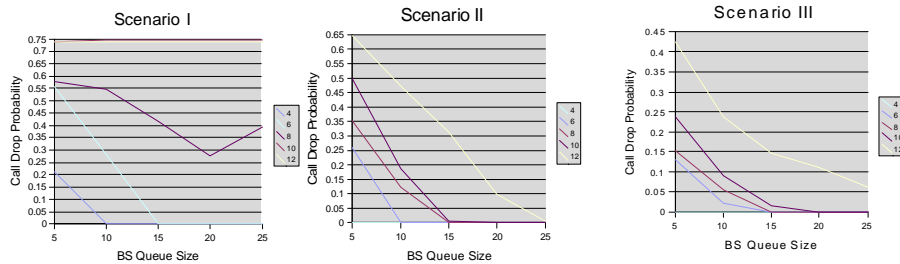


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Effectiveness of the Proposed Algorithm



- **Call Drop Probability falls as Frame size is increased**
- **Call Drop probability falls as BS buffer size is increased**



• **More number of calls can be admitted by increasing frame size without compromising the QoS of admitted call (refer to attached document for detailed analysis)**

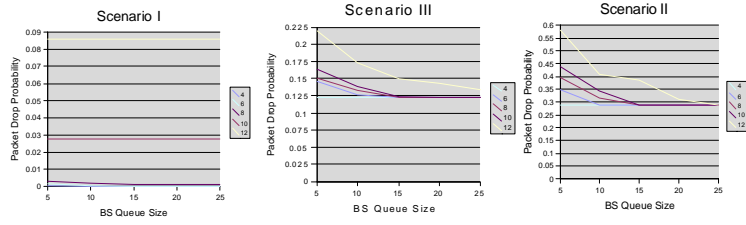


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Effectiveness of Proposed Algorithm.... Cont'd



Ø Call Drop Probability falls as Frame size is increased

Ø Call Drop probability falls as BS buffer size is increased



• Frame duration should be limited to an optimum value (refer to attached document for detailed analysis)