Project	IEEE P802.16 Broadband Wireless Access Working Group
Title	LMDS Cell Sizing and Availability
Date Submitted	9 June, 1999
Source	Robert Duhamel Telcordia Technologies 445 South Street Morristown, NJ 07960 Voice: 973-829-5057 Fax: 973-829-5962 E-mail: rduhamel@telcordia.com
Re:	This is a response to a June 1999 Call for Contributions, for 802.16's Meeting #1 (July 6-8 in Montreal) item #6 " a short statement or summary regarding cell size (capacity) in terms of users and delivered bandwidth to the bearer service."
Abstract	Discussion of equipment transmitter/receiver, antenna and propagation (rain) parameters that dictate both the cell sizing and availability.
Purpose	Provide a guideline for discussion to determine what availability should be used for critical business availability e.g. 99.999%.
Notice	
Release	

Local Multipoint Distribution Service (LMDS) Cell Sizing and Availability

Robert Duhamel

Telcordia Technologies

LMDS System Design Considerations

The most crucial element of a broadband wireless access network design is the determination of the cell layout plan and the types of cells within this plan such as single sectored cells or multiple sectored cells. This requires careful engineering of the intra-hub sectorization plan and hub-to-hub cell growth plan. This in turn influences not only the cell size (bandwidth) but cell radius and availability.

Design Assumptions and Performance Objectives

Trade-offs are required to minimize hubs in order to reduce infrastructure costs.

For discussion the following system design assumptions are made:

- The market target has been established e.g. medium size businesses are interested in multiple DS1 services.

- The hub/sub link example system design assumptions include;
  - Link clearances
    - Line of Sight; locate best buildings
    - .6 Fresnel zone clearance
  - Equipment selection
    - Symmetric Modulation type e.g. QPSK, 16 QAM
    - Access methods e.g. TDM, TDMA and FDMA

The hub/subscriber overall performance objectives or Quality of Service (QoS) goals in this example include;

- Target availability goal of 99.999% with a bit error rate (BER) minimum of 10E-6 or better for 99.999% of the time. See ITU G.826 and F.1189 for further information. The "access" portion may need to be further studied in this area. BER is also now specified as BBER or Block BER. The unavailability goal is .001% or 5.3 minutes rain outage per year when the BER is >10E-6. Rain is the primary source of outages.

Note: The propagation availability; might be specified anywhere between 99.99 to 99.999% or even outside this boundary.

Cell Size (capacity and radius) Selection

- The maximum cell size for the service area is derived from the desired availability level.
- The availability level is used to estimate the maximum distance a subscriber can be located from a cell hub site and still achieve desired link performance.
- The cell size can vary within a coverage area due to the height and type of antenna, foliage loss (this is usually avoided), modulation, rain region and sectorization.
- These effects are generally related to the coverage area type such as urban, suburban or low density coverage.
- The cell size selection affects the total capital cost for the required coverage area.

Availability

- The availability - likelihood (time) that the system will be available to a customer located within the coverage area.
- The unavailability is primarily caused by rain. The signal loss due to rain is widely described by the;
  - Crane Global Model (more conservative i.e. more rain loss)
  - ITU-R Global Model (less conservative i.e. less rain loss)
  - Local rain statistics

Rain Attenuation

Function of:

- Intensity of the rain in mm/hr
- Size of the individual rain drops approaches
  - >=1/4 λ at 28 GHz = .11 inches
  - % of total path within the rain cell
- Fog, snow and ice are negligible at 28 GHz
  - Not significant for short links less than 6 Km (typical for LMDS)

A Generic Example
One Cell or Transmit/Receive Hub

It is assumed that there is one cell (one hub) with 4 90 degree sectors in this example.

- The hub typically transmits to many subscribers within each sector. For simplification, this example includes only two subscribers per sector to allow services approaching DS3 data rates to be distributed throughout each building. Other examples can demonstrate bandwidth on demand solutions to many subscribers with lower data rates e.g. each RF downstream channel may have up to 20 subscribers dedicated to it on the upstream path. For multiple subscribers with lower upstream data rates e.g. 3 Mbps data rates, the subscriber TX power is reduced and the corresponding hub RX sensitivity is increased.

- The RF channels can be increments up to 50 MHz . In this example 40 MHz is assumed.

Example Capacity

- Single hub, frequency reuse=1, 4 sectors

- ~26 DS1s per 40 MHz RF channel for building distribution

- 8 RF channels per hub (400 MHz) with a 50 MHz guard band. Note: 40 of 50 MHz maximum per channel is used.

- 1 x 8 x 26DS1s = 208 DS1s/hub with QPSK modulation

- 416 DS1s/hub with 16 QAM modulation

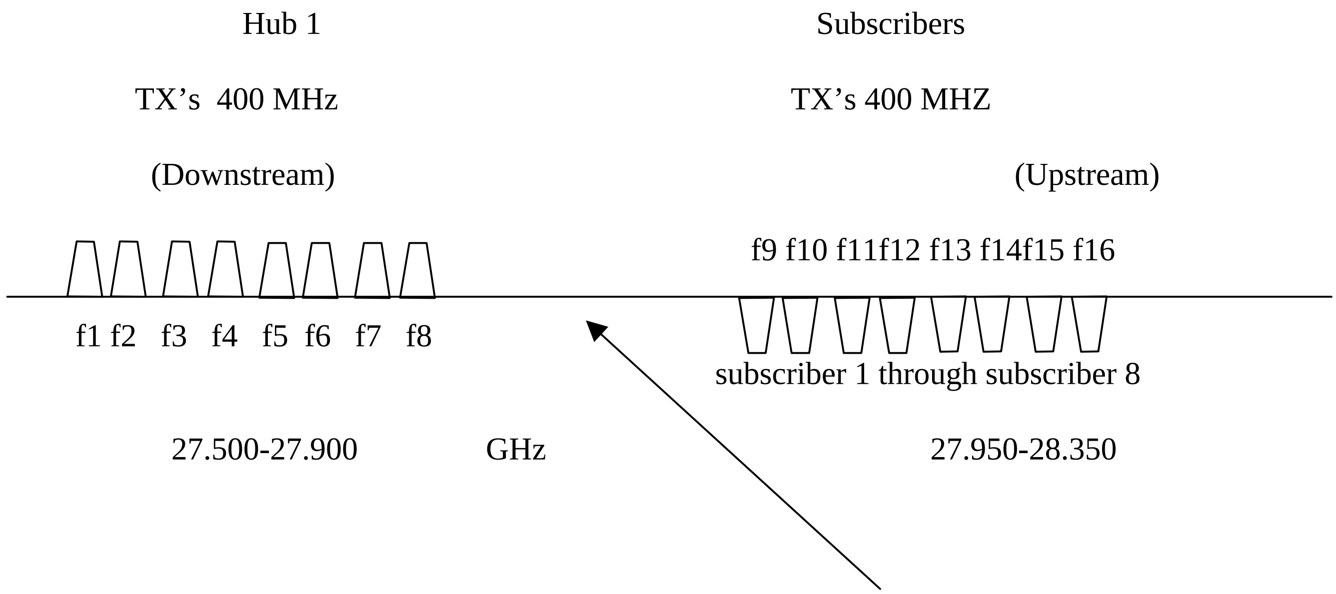
Note: In this example 40 MHz of each 50 MHz RF channel is used therefore 10 MHz in each of eight channels is unused. Spectrum allocation schemes need more study. See Figure 1 example spectrum below.

Figure 1

Example

Block A Spectrum

Frequency Reuse=1



Legend

Sector 1=f1,f2 where f_n= +/-20 MHz

Sector 2=f3,f4

Sector 3=f5,f6

Sector 4=f7,f8

Guard Band (if necessary)
27.900-27.950
dependent on
manufacturer

Notes:

1. Reference CCIR Rec. 749 as guide.
2. Option: For lower upstream data rates e.g. 3 Mbps, the subscriber bandwidth may equal +/- 1 MHz e.g. f1 could transmit to 20 subscribers. Twenty FDMA upstream carriers could replace one 40 MHz F9 carrier.

Propagation Availability

After the spectrum allocation plan is determined the hub to subscriber link availability or cell radius as a function of the rain loss must be determined.

The assumed values in Table 1 directly affect the cell size.

Table 1
Rain Attenuation - dB @ 1 km
For Rain Region D1

Block A	99.99%	99.999%
28 GHz	7.5	18.6
Rain Rate (mm/hr)	37	90

Notes: The above rain attenuation is derived from the "*Prediction of Attenuation by Rain*" by Robert K. Crane, 1980. It includes the calculation procedure to arrive at these values. These values are later used in the hub to subscriber links budgets.

After performing link budget calculations (Reference Table 3 and Table 4) we arrive at the following cell size and capacity results.

Table 2
Example
Cell Size/Capacity
Link Budget Results for Hub1

	QPSK		**16 QAM**	
Rain Availability	99.99%	99.999%	99.99%	99.999%
Per Hub Cell Size	1.6 mi. (2.6 Km)	.9 mi. (1.44 Km)	1.2 mi. (1.9 Km)	.7 mi. (1.1 Km)
Per Hub Capacity(DS1's)	208		416	

Notes:
For D1 Rain Region, Frequency reuse=1, 4 90 degree sectors each sector 100 MHz, 8 RF carriers (50 MHz guardband)

Table 3
Example (Downstream) Link Budget
Hub to Sub Link
16 QAM: 99.999% Availability

Frequency	28 GHz	
Hub Transmit Power Spectral Density	-16 dBW/MHz	+30 dBm per 40 MHz
Hub Power Back-Off	0 dB	
Hub TX Coax Line Loss	3 dB	
Hub TX Antenna Gain	15 dBi	
Hub EIRP	-4 dBW/MHz	
Free Space Loss	122.4 dB	**Crane cell radius .7 mi. (1.1 Km)**
Band Edge Allowance Normally 3db	0 dB	
Rainfall Allowance	18.6 dB	**99.999% Crane availability** Crane Rain Global Model at Rain Region D1
Sub RX Antenna Gain	31 dBi	
Sub RX Coax Line Loss	3 dB	
Sub Minimum Receiver Power (RCL) With Rain Fade	–117.0 dBW/MHz	-71.0 dBm per 40 MHz
Sub Minimum Receiver Power (RCL) Without Rain Fade		-52.4 dBm per 40 MHz
Sub Receive Threshold Or Sensitivity (NF=6 dB)	-138 dBW/MHz	-92.0 dBm per 40 MHz
Sub C/N With Rain (BER of 10E-6)	21.0 dB	
Sub C/N Without Rain	39.6 dB	
Coding Gain	0	
Implementation	0	
Excess Link Margin @ Max Rainfall	0 dB	required for diffraction, ground reflections and path obstructions

Notes:

1. Above values are for 0 dB excess link margin. It is assumed that there are no path obstructions i.e. all links to subscribers are line-of-sight (LOS) with .6 Fresnel clearance. It is also assumed that diffraction and ground reflections are negligible.

Table 4

Example (Upstream) Link Budget

Sub to Hub Link

16 QAM: 99.999% Availability

Frequency	28 GHz	
Sub Transmit Power Spectral Density	-16 dBW/MHz	+30 dBm per 40 MHz(Note 4)
Sub Power Back-Off	0 dB	
Sub TX Coax Line Loss	3 dB	
Sub TX Antenna Gain	31 dBi	
Sub EIRP	+12 dBW/MHz	
Free Space Loss	122.4 dB	**Crane cell radius .7 mi. (1.1 Km)**
Band Edge Allowance Normally 3db	0 dB	
Rainfall Allowance	18.6 dB	**99.999% Crane availability** Crane Rain Global Model at Rain Region D1
Hub RX Antenna Gain	15 dBi	
Hub RX Coax Line Loss	3 dB	
Hub Minimum Receiver Power (RCL) With Rain Fade	–117.0 dBW/MHz	-71.0 dBm per 40 MHz(Note 4)
Hub Minimum Receiver Power (RCL) Without Rain Fade		-52.4 dBm per 40 MHz(Note 4)
Hub Receive Threshold Or Sensitivity (NF=6 dB)	-138 dBW/MHz	-92.0 dBm per 40 MHz(Note 4)
Hub C/N With Rain (BER of 10E-6)	21.0 dB	
Hub C/N Without Rain	39.6 dB	
Coding Gain	0	
Implementation	0	
Excess Link Margin @ Max Rainfall	0 dB	required for diffraction, ground reflections and path obstructions

Notes:

1. Above table is for 0 dB excess link margin. It is assumed that there are no path obstructions i.e. all links to subscribers are line-of-sight (LOS) with .6 Fresnel clearance. It is also assumed that diffraction and ground reflections are negligible.
2. No uplink power control. Power control would allow the subscribers to adjust their TX power as the rain attenuation increase or decreases e.g. 18.6 dB of attenuation requires +30 dBm TX power but 0 dB rain attenuation would require +11.4 dBm TX power. This is particularly useful for a large number of subscribers because it minimizes the aggregate upstream RFI in a multi-hub or frequency reuse scenario.
3. BER minimum of 10E-6 should meet minimum ~BBER of 10E-05 at C/(N+I) in Table 3 of Rec. ITU-R F.1189-1. Assumes a single link between path end point (CPE) and the corresponding local access switching center (local exchange).
4. For smaller upstream data rates e.g. 3 Mbps the Subscriber TX power is reduced to +17 dBm, Hub RX RCL=-84 dBm with rain, and –65.4 dBm without rain and Hub RX threshold to –105 dBm in a 2 MHz bandwidth.

Other engineering considerations

- More elaborate Hub RF sectorization plans that increase capacity such as twelve 30 degree sectors.
- Using frequency reuse of 2 and higher. Placing hubs on alternating polarizations will double bandwidth capacity because the frequency reuse of 2 uses the same frequency set on H and V polarization on each sector.

  Note; Using frequency reuse has an element of risk because V and H polarization isolation and depolarization must be sufficient to preclude subscriber RFI. Antenna radiation patterns must be closely evaluated to increase frequency reuse. See CCIR 746 1991, Fig. 1 for cross polarization definition.

Required Interference Reduction Techniques

- Reduce RFI using polarization reuse; minimum co-channel threshold requirement
- Matrix cellular arrangement of hubs to reduce co-channel RFI
- Worst case RFI in matrix or other cellular arrangement
- Frequency and polarization reuse at adjacent hubs and/or sectors

Modulation schemes

- QPSK Robust modulation vs. QAM
- Hybrid modulation can be used within the same sector e.g. more traffic density may be closer to the hub in a sector therefore 64 QAM carrier may be used with a QPSK carrier for more distant traffic.

Backhaul Trunking Options

- Microwave vs. Fiber Optic backhaul
  - Error Definitions
  - Availability

- Design Considerations
  - Similar to LMDS
  - P-P
  - Star configuration uses least bandwidth
  - Other frequency bands are available
    - e.g. 18 to 40 GHz

Interface with National Network

See Hypothetical Reference Path Figure 1 in ITU-R F.1189-1 for Access, Short Haul

Long Haul Error Performance Objectives.

References

1. R. K. Crane, “Prediction of Attenuation by Rain” IEEE, 1980.

2. ITU-T G.826: Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate (2/99).

3. ITU-R F.1189-1 Error performance objectives for constant bit rate digital paths at or above the primary rate carried by digital radio-relay systems which may form part or all of the national portion of a 27500 km hypothetical reference path. (1995-1997).

4. CCIR Recommendation 749, Radio-Frequency channels arrangements for radio-relay systems operating in the 36.0 to 40.5 GHz band. (1992).