FibeAir® IP-10

Product Description

Document Version 1.7

July 2008

CARRIER ETHERNET
MEF
Certified Compliant

Important Notice

This document is delivered subject to the following conditions and restrictions:

This document contains proprietary information belonging to Ceragon Networks Ltd.

Ceragon Networks Ltd. owns the proprietary rights to all information contained herein. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, magnetic, photocopy, recording, or otherwise, now or in the future, without prior written consent from Ceragon Networks Ltd.

The text and graphics are for illustration and reference only. The specifications on which they are based are subject to change without notice.

Due to a policy of continuous development, Ceragon Networks Ltd. reserves the right to alter specifications and descriptions outlined in this publication without prior notice, and no part of this publication, taken separately or as a whole, shall be deemed to be part of any contract.

Ceragon Networks®, CeraView®, FibeAir® and the FibeAir® design mark are registered trademarks of Ceragon Networks Ltd., and Ceragon™, PolyView™, ConfigAir™, CeraMon™, EtherAir™, QuickAir™, QuickAir Partner Program™, QuickAir Partner Certification Program™, QuickAir Partner Zone™, EncryptAir™ and Microwave Fiber™ are trademarks of Ceragon Networks Ltd.

All other product names are trademarks or registered trademarks of their respective owners.

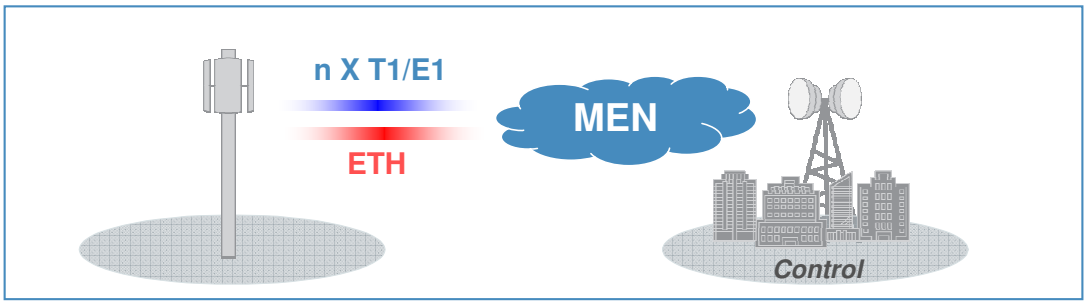
Contents

Introducing FibeAir IP-10

FibeAir IP-10 is Ceragon's comprehensive high capacity IP and Migration-to-IP network solution. The innovative IP-10 was designed as a native Ethernet microwave radio platform that can integrate smoothly in any network, while providing a broad range of software-configurable licensed channel schemes.

IP-10 follows in the tradition of Ceragon's Native^2, which allows your network to benefit from both native TDM and native Ethernet using the same radio. Flexible bandwidth sharing between the TDM and Ethernet traffic ensures optimal throughput for all your media transfer needs.

With the Metro Ethernet Networking trend growing, IP-10 is poised to fill in the gap and deliver high capacity IP communication quickly, easily, and reliably.



IP-10 features impressive market-leading throughput capability together with advanced networking functionality.

Some of the quick points that place IP-10 at the top of the wireless IP offerings:

- Supports all licensed bands, from 6 to 38 GHz
- Supports channel bandwidths of from 7 MHz to 56 MHz
- Supports throughputs of from 10 to 500 Mbps per radio carrier (QPSK to 256 QAM)
- Incorporates advanced integrated Ethernet switching capabilities

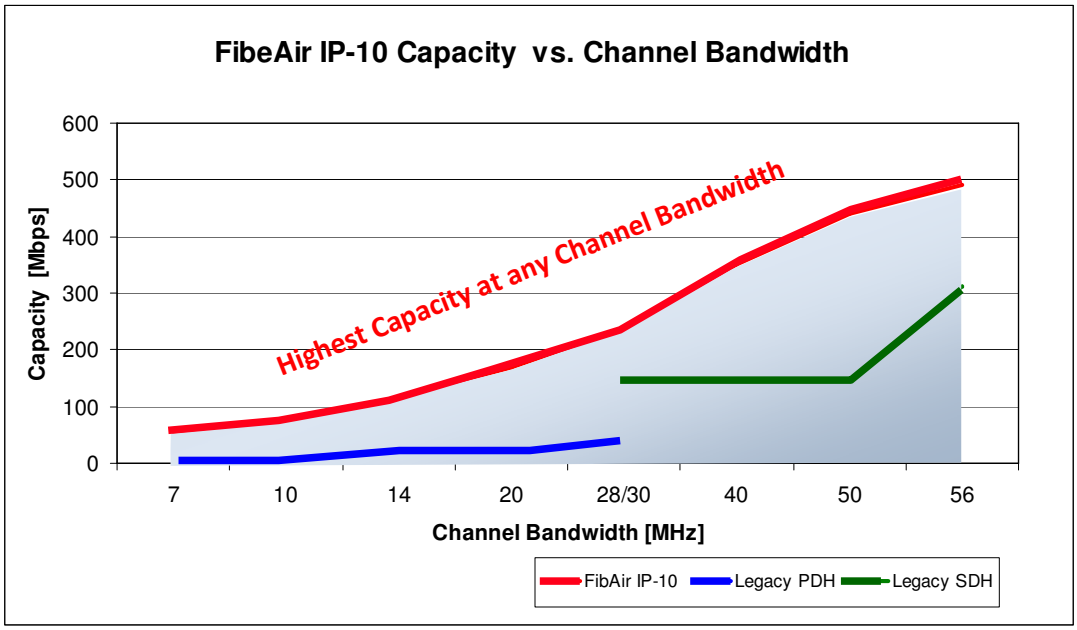
In addition, using unique Adaptive Coding & Modulation (ACM), your network benefits from non-stop, dependable, capacity deliverance.

FibeAir IP-10

Features

Highest Spectral Efficiency

- Modulations: QPSK to 256 QAM
- Radio capacity:
  - ETSI – up to 50/100/220/280/500 Mbps over 7/14/28/40/56 MHz channels
  - FCC – up to 70/140/240/320/450 Mbps over 10/20/30/40/50 MHz channels
- All licensed bands: L6, U6, 7, 8, 10, 11, 13, 15, 18, 23, 26, 28, 32, 38 GHz
- Highest scalability: From 10 Mbps to 500 Mbps, using the same hardware, including the same ODU/RFU!
- Configurations: 1+0 or 1+1 Hot Standby (fully redundant)



Native^2 Microwave Radio Technology

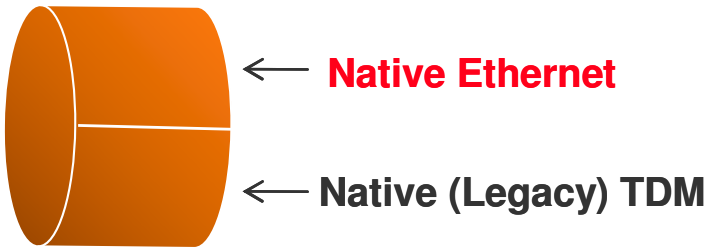
At the heart of the IP-10 solution is Ceragon's market-leading Native^2 microwave technology.

With this technology, the microwave carrier supports native IP/Ethernet traffic together with optional native PDH. Neither traffic type is mapped over the other, while both dynamically share the same overall bandwidth.

This unique approach allows you to plan and build optimal all-IP or hybrid TDM-IP backhaul networks which make it ideal for any RAN (Radio Access Network) evolution path selected by the wireless provider (including Green-Field 3.5G/4G all-IP installations).

In addition, Native^2 ensures:

- Very low link latency of <0.15 msecs @ 400 Mbps.
- Very low overhead mapping for both Ethernet and TDM traffic, to the microwave radio frame.
- High precision native TDM synchronization distribution.

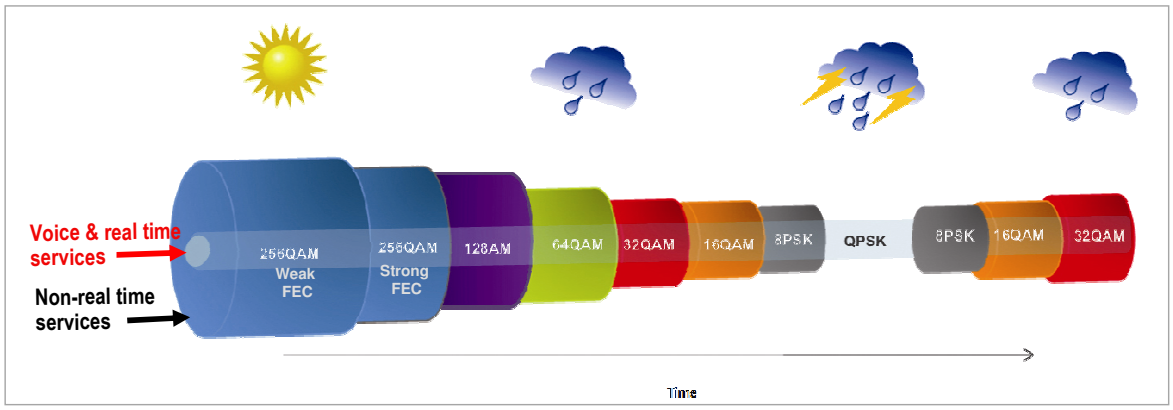


Adaptive Coding & Modulation

ACM employs the highest possible modulation during changing environmental conditions, which may be from QPSK to 256 QAM.

The benefits of this dynamic feature include:

- Maximized spectrum usage
- Increased capacity over a given bandwidth
- 8 modulation/coding work points (~3 db system gain for each point change)
- Supports both Ethernet and T1/E1 traffic
- Hitless and errorless modulation/coding changes, based on signal quality
- T1/E1 traffic has priority over Ethernet traffic
- An integrated QoS mechanism enables intelligent congestion management to ensure that your high priority traffic is not affected during link fading.
- Each T1/E1 is assigned a priority to enable differentiated T1/E1 dropping during severe link degradation.

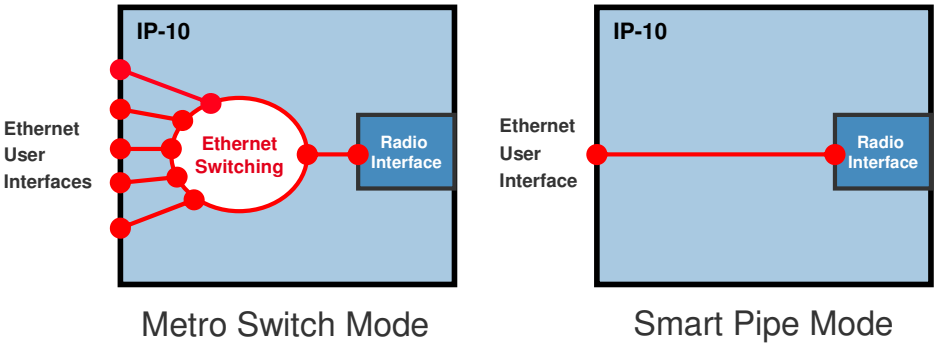


Integrated Layer-2 Switching

IP-10 supports two modes for Ethernet switching:

Smart Pipe - In this mode, Ethernet switching functionality is disabled and only a single Ethernet interface is enabled for user traffic. The unit effectively operates as a point-to-point Ethernet microwave radio.

Metro Switch - In this mode, Ethernet switching functionality is enabled.



With the switch activated, the following features are supported:

- Fully non-blocking switching between all line/radio interfaces
- 4K active VLANs
- 8K MAC addresses
- 802.1ad provider bridges (QinQ) support for VLAN stacking
- Integrated QoS
- Full RMON/ROM2 statistics per interface
- Ethernet service OAM - 802.1ag/Y.1731
- Ethernet link OAM – 802.3ah
- 802.3ad link aggregation
- STP/RSTP/MSTP for protection and loop-prevention with load balancing

IP-10 is fully MEF-9 and MEF-14 certified for EPL, EVPL and E-LAN services.

QoS-Aware Dynamic Congestion Management (with ACM)

- Four priority (CoS) queues
- Advanced CoS classifier: 802.1p, VLAN ID, IPv4 / IPv6 (DSCP/TOS/TC).
- Advanced ingress traffic policing/rate-limiting per port/CoS
- Flexible scheduling: Strict Priority, Weighted Round Robin, or hybrid.
- Traffic shaping
- 802.3x flow control (for loss-less) operation

Intelligent Ethernet Header Compression (patent-pending)

- Improves effective throughput by up to 45%!
- Does not affect user traffic.

Ethernet packet size (bytes)	Capacity increase by compression
64	45%
96	29%
128	22%
256	11%
512	5%

Extensive Radio Capacity/Utilization Statistics

- Statistics are collected at 15-minute and 24-hour intervals
- Historical statistics are stored and made available when needed
- Capacity/ACM statistics:
  - Maximum modulation in interval
  - Minimum modulation in interval
  - # of seconds in an interval, during which active modulation was below the user-configured threshold
- Utilization statistics:
  - Maximal radio link utilization in an interval
  - Average radio link utilization in an interval
  - # of seconds in an interval, during which radio link utilization was above the user-configured threshold

In-Band Management

IP-10 can optionally be managed in-band, via its radio and Ethernet interfaces. This method of management eliminates the need for a dedicated interface and network.

In-band management uses a dedicated management VLAN, which is user-configurable.

Native TDM Base Station Timing & Synchronization

Each T1/E1 trail carries a native TDM clock, which is compliant with strict cellular application requirements (2G/3G), and is suitable as a base station timing source.

This eliminates the need for timing-over-packet techniques for base station synchronization.

Advantages

IP-10 has many advantages that cover the many aspects of flexible and reliable network building.

Incomparable Economic Value!

The IP-10 pay-as-you-grow concept reduces network costs. Each network node is optimized individually, with future capacity growth in mind.

Whenever needed, additional functionality is enabled via upgrade license, using the same hardware. Using this flexible economic approach, a full duplex throughput of more than 400 Mbps over a single channel can be achieved.

Experience Counts!

IP-10 was designed with continuity in mind. It is based on Ceragon's well-established and field-proven IP-MAX Ethernet microwave technology.

With Ceragon's large install base, years of experience in high-capacity IP radios, and seamless integration with all standard IP equipment vendors, IP-10 is poised to be an IP networking standard-bearer.

Native^2!

With Native^2, you get optimal all-IP or hybrid TDM-IP backhaul networking - ideal for any RAN evolution path!

User-Management Traffic Integration

In-Band Management significantly simplifies backhaul network design and maintenance, reducing both Capex and Opex. It also dramatically improves overall network availability and reliability, enabling support for services with stringent SLA (Service Level Agreement).

Unique Full Range Adaptive Modulation

Provides the widest modulation range on the market from QPSK to 256 QAM with multi-level real-time hitless and errorless modulation shifting changing dynamically according to environmental conditions - while ensuring zero downtime connectivity.

Guaranteed Ultra Low Latency (< 0.15 ms @ 400Mbps)

Suitable for delay-sensitive applications, such as VoIP and Video over IP.

Extended Quality of Service (QoS) Support

Enables smart packet queuing and prioritization.

Fully Integrated L2 Ethernet Switching Functionality

Including VLAN based switching, MAC address learning, QinQ and STP/RSTP/MSTP support.

Multiple Network Topology Support

Mesh, Ring, Chain, Point-to-Point.

Longer Transmission Distances, Smaller Antennas

Reduces network costs and enables a farther reach to the other end.

Applications

Mobile backhaul

Cellular Networks

FibeAir IP-10 family supports both Ethernet and TDM for cellular backhaul network migration to IP, within the same compact footprint. The system is suitable for all migration scenarios where carrier-grade Ethernet and legacy TDM services are required simultaneously.

WiMAX Networks

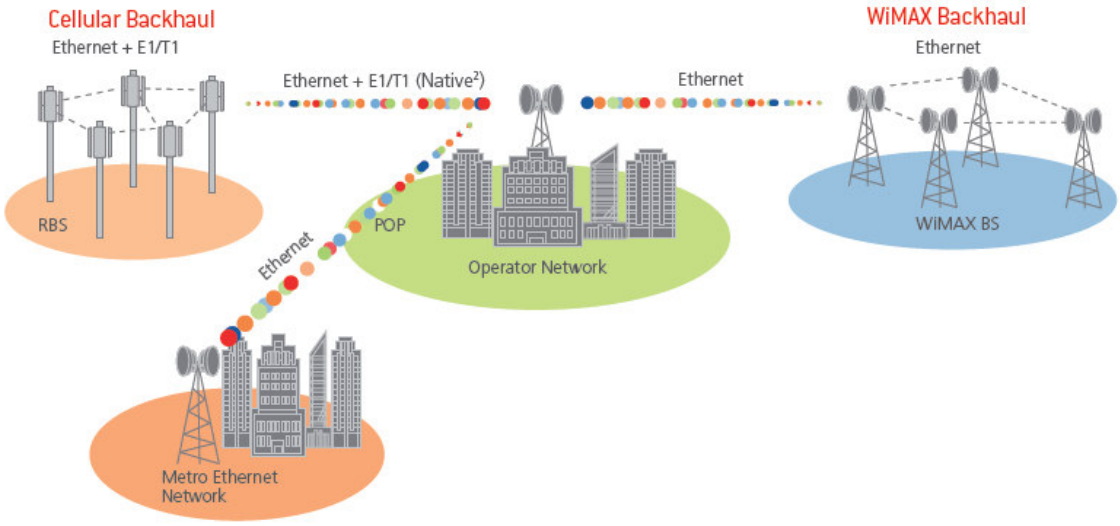
Enabling connectivity between WiMAX base stations and facilitating the expansion and reach of emerging WiMAX networks, FibeAir IP-10 provides a robust and cost-efficient solution with advanced native Ethernet capabilities.

FibeAir IP-10 family offers cost-effective, high-capacity connectivity for carriers in cellular, WiMAX and fixed markets. The FibeAir IP-10 platforms supports multi-service and converged networking requirements for both legacy and the latest data-rich applications and services.

Converged Fixed/Wireless Networks

Ceragon's FibeAir IP-10 delivers integrated high speed data, video and voice traffic in the most optimum and cost-effective manner. Operators can leverage FibeAir IP-10 to build a converged network infrastructure based on high capacity microwave to support multiple types of service.

FibeAir IP-10 is fully compliant with MEF-9 & MEF-14 standards for all service types (EPL, EVPL and E-LAN) making it the ideal platform for operators looking to provide high capacity Carrier Ethernet services meeting customers demand for coverage and stringent SLA.

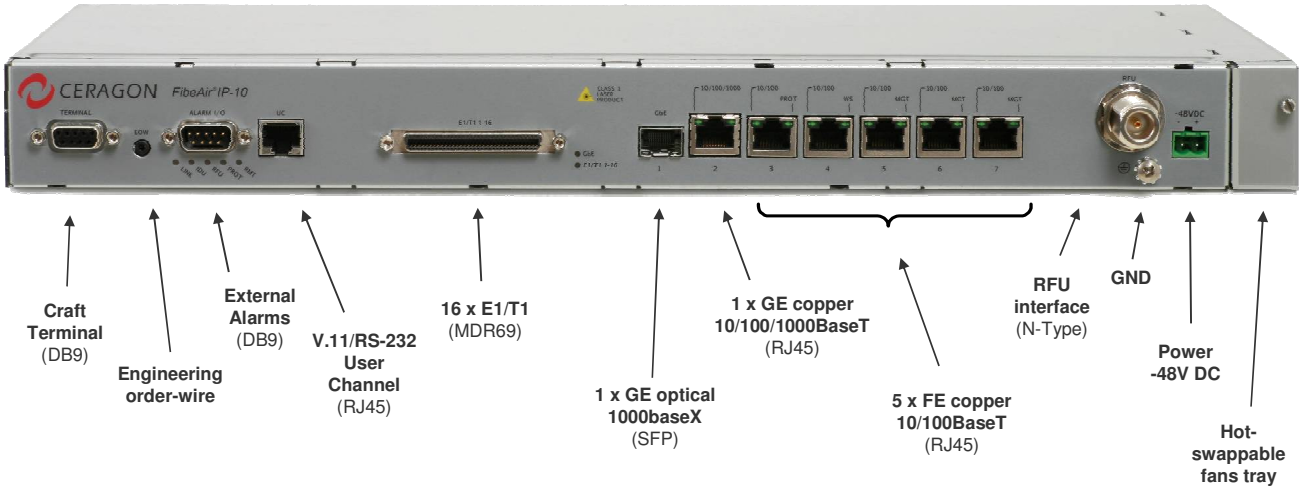


Typical FibeAir IP-10 Applications

System Overview

General

- Split-mount architecture (IDU and RFU/ODU)
- Compatible with all existing Ceragon RFUs/ODUs.
- Dimensions
  - Height: 42.6 mm (1RU)
  - Width: 439 mm (<19")
  - Depth: 188 mm (fits in ETSI rack)
- DC input voltage nominal rating: -48V



IP-10 front panel and interfaces

Interfaces

Main interfaces:

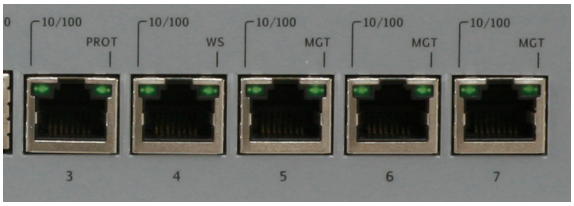
- 5 x 10/100Base-T
- 1 x 10/100/1000Base-T
- 1 x SFP 1000Base-X
- 16 x T1/E1 (optional)
- RFU/ODU interface, N-type connector

Additional interfaces:

- Terminal console
- AUX package (optional):
    - Engineering Order Wire (EOW)
    - User channel (V.11 async, RS-232)
    - External alarms (4 inputs & 1 output)

In addition, each of the FE traffic interfaces can be configured to support an alternate mode of operation:

- MGT: Ethernet out-of-band management (up to 3 interfaces)
- WS: Ethernet wayside
- PROT: Ethernet protection control interface (for 1+1 HSB mode support)



Available assembly options:

- TDM options:
    - Ethernet only (no TDM)
    - Ethernet + 16 x E1
    - Ethernet + 16 x T1
- With or without AUX package (EOW, User channel & alarms)

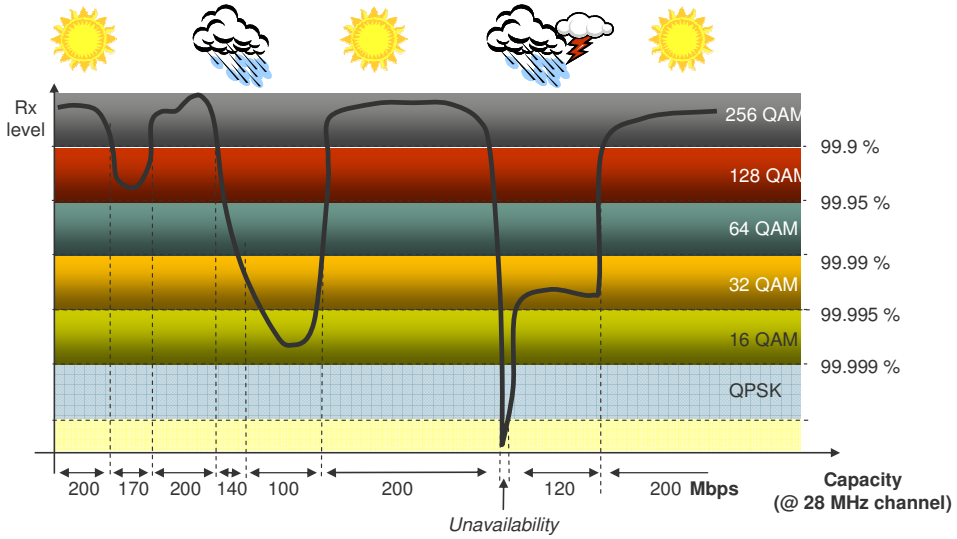
Adaptive Coding and Modulation

Adaptive Coding and Modulation refers to the automatic adjustment that a wireless system can make in order to optimize over-the-air transmission and prevent weather-related fading from causing communication on the link to be disrupted. When extreme weather conditions, such as a storm, affect the transmission and receipt of data and voice over the wireless network, an ACM-enabled radio system automatically changes modulation allowing real-time applications to continue to run uninterrupted. Varying the modulation also varies the amount of bits that are transferred per signal, thereby enabling higher throughputs and better spectral efficiencies. For example, a 256 QAM modulation can deliver approximately four times the throughput of 4 QAM (QPSK).

Ceragon Networks employs full-range dynamic ACM in its new line of high-capacity wireless backhaul product - FibeAir IP-10. In order to ensure high transmission quality, Ceragon solutions implement hitless/errorless ACM that copes with 90dB per second fading. A quality of service awareness mechanism ensures that high priority voice and data packets are never “dropped”, thus maintaining even the most stringent service level agreements (SLAs).

The hitless/errorless functionality of Ceragon’s ACM has another major advantage in that it ensures that TCP/IP sessions do not time-out. Lab simulations have shown that when short fades occur (for example if a system has to terminate the signal for a short time to switch between modulations) they may lead to timeout of the TCP/IP sessions – even when the interruption is only 50 milliseconds. TCP/IP timeouts are followed by a drastic throughput decrease over the time it takes for the TCP sessions to recover. This may take as long as several seconds. With a hitless/errorless ACM implementation this problem can be avoided.

So how does it really work? Let's assume a system configured for 128 QAM with ~170 Mbps capacity over a 28 MHz channel. When the receive signal Bit Error Ratio (BER) level arrives at a predetermined threshold, the system will preemptively switch to 64 QAM and the throughput will be stepped down to ~140 Mbps. This is an errorless, virtually instantaneous switch. The system will then run at 64 QAM until the fading condition either intensifies, or disappears. If the fade intensifies, another switch will take the system down to 32 QAM. If on the other hand the weather condition improves, the modulation will be switched back to the next higher step (e.g. 128QAM) and so on, step by step .The switching will continue automatically and as quickly as needed, and can reach during extreme conditions all the way down to QPSK.


Rx
level
256 QAM
128 QAM
64 QAM
32 QAM
16 QAM
QPSK
99.9 %
99.95 %
99.99 %
99.995 %
99.999 %
200
170
200
140
100
200
120
200 Mbps
Capacity
(@ 28 MHz channel)
Unavailability

Adaptive Modulation and Built-in Quality of Service

Ceragon's Adaptive Modulation has a remarkable synergy with the equipment's built-in Layer 2 Quality of Service mechanism. Since QoS provides priority support for different classes of service, according to a wide range of criteria (see below) it is possible to configure the system to discard only low priority packets as conditions deteriorate. The FibeAir IP-10 platform can classify packets according to the most external header, VLAN 802.1p, TOS / TC - IP precedence and VLAN ID. All classes use 4 levels of prioritization with user selectable options between strict priority queuing and weighted fair queuing with user configurable weights.

If the user wishes to rely on external switches QoS, Adaptive Modulation can work with them via the flow control mechanism supported in the radio.

Quality of Service (QoS)

Traffic Classification and policing

The system examines the incoming traffic and assigns the desired priority according to the marking of the packets (based on the user port/L2/L3 marking in the packet). In case of congestion in the ingress port, low priority packets will be discarded first.

The user has the following classification options:

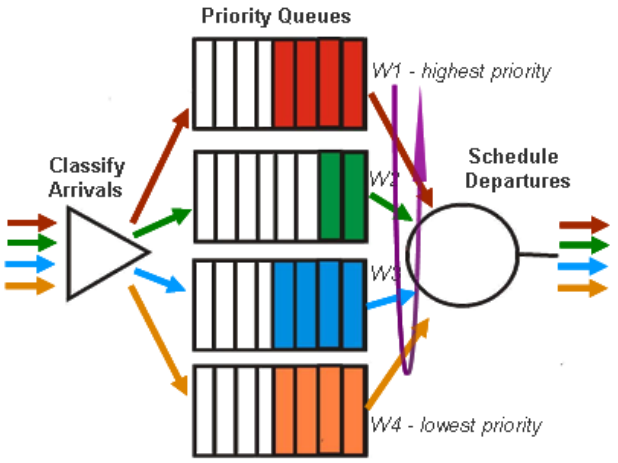
- Source Port
- VLAN 802.1p
- VLAN ID
- IPv4 TOS/DSCP
- IPv6 Traffic Class

After classification traffic policing/rate-limiting can optionally be applied per port/CoS.

Queuing and Scheduling

The system has four priority queues that are served according to three types of scheduling, as follows:

- Strict priority: all top priority frames egress towards the radio until the top priority queue is empty. Then, the next lowest priority queue's frames egress, and so on. This approach ensures that high priority frames are always transmitted as soon as possible.
- Weighted Round Robin (WRR): each queue can be assigned with a user-configurable weight from 1 to 32.
- Hybrid: One or two highest priority queues as "strict" and the other according to WRR



Shaping is supported per interface on egress.

Ethernet Statistics

The FibeAir IP-10 platform stores and displays statistics in accordance with RMON and RMON2 standards.

The following groups of statistics can be displayed:

- Ingress line receive statistics
- Ingress radio transmit statistics
- Egress radio receive statistics
- Egress line transmit statistics

The statistics that can be displayed within each group include the following:

Ingress Line Receive Statistics

- Sum of frames received without error
- Sum of octets of all valid received frames
- Number of frames received with a CRC error
- Number of frames received with alignment errors
- Number of valid received unicast frames
- Number of valid received multicast frames
- Number of valid received broadcast frames
- Number of packets received with less than 64 octets
- Number of packets received with more than 12000 octets (programmable)
- Frames (good and bad) of 64 octets
- Frames (good and bad) of 65 to 127 octets
- Frames (good and bad) of 128 to 256 octets
- Frames (good and bad) of 256 to 511 octets
- Frames (good and bad) of 512 to 1023 octets
- Frames (good and bad) of 1024 to 1518 octets
- Frames (good and bad) of 1519 to 12000 octets

Ingress Radio Transmit Statistics

- Sum of frames transmitted to radio
- Sum of octets transmitted to radio
- Number of frames dropped

Egress Radio Receive Statistics

- Sum of valid frames received by radio
- Sum of octets of all valid received frames
- Sum of all frames received with errors

Egress Line Transmit Statistics

- Sum of valid frames transmitted to line
- Sum of octets transmitted

Notes:

- Statistic parameters are polled each second, from system startup.
- All counters can be cleared simultaneously.
- The following statistics are displayed every 15 minutes (in the Radio and E1/T1 performance monitoring windows):
- Utilization - four utilizations: ingress line receive, ingress radio transmit, egress radio receive, and egress line transmit
- Packet error rate - ingress line receive, egress radio receive
- Seconds with errors - ingress line receive

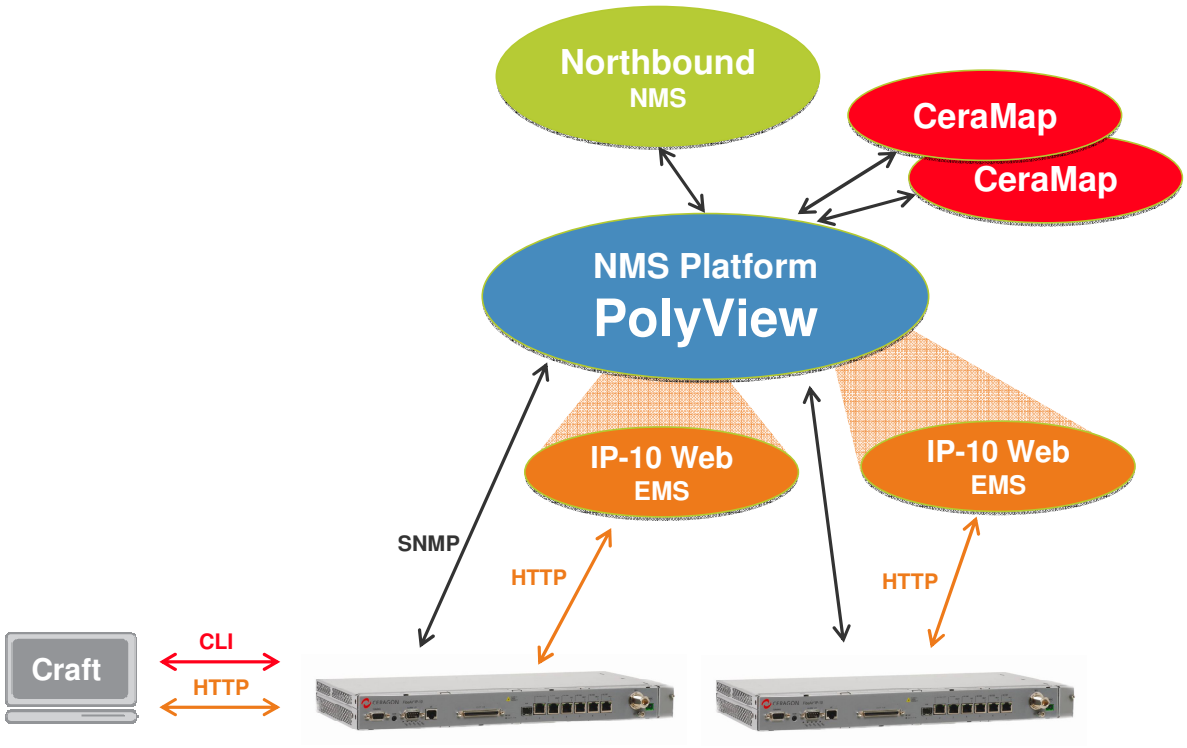
End-To-End Network Management

Ceragon provides state-of-the-art management based on SNMP and HTTP.

Integrated Web Based Element Manager: Each device includes an HTTP based element manager that enables the operator to perform element configuration, RF, Ethernet, and PDH performance monitoring, remote diagnostics, alarm reports, and more.

PolyView™ is Ceragon's NMS server that includes CeraMap™ its friendly and powerful client graphical interface. PolyView can be used to update and monitor network topology status, provide statistical and inventory reports, define end-to-end traffic trails, download software and configure elements in the network. In addition, it can integrate with Northbound NMS platforms, to provide enhanced network management.

The application is written in Java code and enables management functions at both the element and network levels. It runs on Windows 2000/2003/XP/Vista and Sun Solaris.



Integrated IP-10 Web EMS and PolyView NMS

FibeAir IP-10 & FibeAir RFUs

FibeAir IP-10 is based on the latest Ceragon technology, and can be installed together with any FibeAir RFU, including:

- FibeAir 1500HP (FibeAir RFU-HP)
- FibeAir 1500SP (FibeAir RFU-SP)
- FibeAir 1500P (FibeAir RFU-P)
- FibeAir RFU-C

FibeAir RFUs support multiple capacities, frequencies, modulation schemes, and configurations for various network requirements.

The RFUs operate in the frequency range of 6-38 GHz, and support capacities of from 10 Mbps to 500 Mbps, for TDM and IP interfaces.

For more information, see the relevant RFU Product Description.

IP-10 works with

FibeAir RFU-HP

FibeAir RFU-SP

FibeAir RFU-P

FibeAir RFU-C

Specifications

Radio Specifications

General

6-18 GHz

Specification	6L,6H GHz	7,8 GHz	11 GHz	13 GHz	15 GHz	18 GHz
Standards	ETSI, FCC	ETSI	ETSI, FCC	ETSI	ETSI	ETSI, FCC
Operating Frequency Range (GHz)	5.85-6.45, 6.4-7.1	7.1-7.9, 7.7-8.5	10.7-11.7	12.75-13.3	14.4-15.35	17.7-19.7
Tx/Rx Spacing (MHz)	252.04, 240, 266, 300, 340, 160, 170, 500	154, 161, 168, 182, 196, 245, 300, 119, 311.32	490, 520, 530	266	315, 420, 644, 490, 728	1010, 1120, 1008, 1560
Frequency Stability	+0.001%					
Frequency Source	Synthesizer					
RF Channel Selection	Via EMS/NMS					
System Configurations	Non-Protected (1+0), Protected (1+1), Space Diversity					
Tx Range (Manual/ATPC)	20dB dynamic range					

23-38 GHz

Specification	23 GHz	24-26 GHz	28 GHz	32 GHz	38 GHz
Standards	ETSI, FCC	ETSI, FCC	ETSI, FCC	ETSI, FCC	ETSI, FCC
Operating Frequency Range (GHz)	21.2-23.65	24.2-26.5	27.35-31.3	31.8-33.4	37-40
Tx/Rx Spacing (MHz)	1008, 1200, 1232	800, 900, 1008	350, 500, 1008	812	1000, 1260, 700
Frequency Stability	+0.001%				
Frequency Source	Synthesizer				
RF Channel Selection	Via EMS/NMS				
System Configurations	Non-Protected (1+0), Protected (1+1), Space Diversity				
Tx Range (Manual/ATPC)	20dB dynamic range				

RFU support

Split-Mount installation	FibeAir RFU-C (6 – 38 GHz)[1] FibeAir RFU-P (11 – 38 GHz) FibeAir RFU-SP (6 – 8 GHz) FibeAir RFU-HP (6 – 11 GHz)
All-Indoor installation	FibeAir RFU-HP (6 – 11 GHz)
IDU to RFU connection	Coaxial cable RG-223 (100 m/300 ft), Belden 9914/RG-8 (300 m/1000 ft) or equivalent, N-type connectors (male)
Antenna Connection	Direct or remote mount using the same antenna type. Remote mount: standard flexible waveguide (frequency dependent)

Note: For more details about the different RFUs refer to the RFU documentation.

[1] Refer to RFU-C roll-out plan for availability of each frequency.

Capacity

7 MHz (ETSI)

Working Point	Modulation	Minimum required capacity license	Number of Supported E1s	Ethernet Throughput	
				Min	Max
1	QPSK	10	4	9.5	13.5
2	8 PSK	25	6	14	20
3	16 QAM	25	8	20	28
4	32 QAM	25	10	23	34
5	64 QAM	25	12	28	40
6	128 QAM	50	13	33	47
7	256 QAM	50	16	38	55
8	256 QAM	50	16	43	60

Note: Ethernet throughput depends on average packet size.

10 MHz (FCC)

Working Point	Modulation	Minimum required capacity license	Number of Supported T1s	Ethernet Throughput	
				Min	Max
1	QPSK	10	7	13	18
2	8 PSK	25	10	19	27
3	16 QAM	25	16	28	40
4	32 QAM	50	16	32	46
5	64 QAM	50	16	42	61
6	128 QAM	50	16	50	71
7	256 QAM	50	16	54	78
8	256 QAM	50	16	61	87

Note: Ethernet throughput depends on average packet size.

14 MHz (ETSI)

Working Point	Modulation	Minimum required capacity license	Number of supported E1s	Ethernet Throughput	
				Min	Max
1	QPSK	25	8	20	29
2	8 PSK	25	12	28	40
3	16 QAM	50	16	38	54
4	32 QAM	50	16	50	71
5	64 QAM	50	16	57	82
6	128 QAM	100	16	69	99
7	256 QAM	100	16	81	115
8	256 QAM	100	16	90	128

Note: Ethernet throughput depends on average packet size.

20 MHz (FCC)

Working Point	Modulation	Minimum required capacity license	Number of supported T1s	Ethernet Throughput	
				Min	Max
1	QPSK	25	16	28	40
2	8 PSK	50	16	39	56
3	16 QAM	50	16	57	81
4	32 QAM	100	16	67	96
5	64 QAM	100	16	93	133
6	128 QAM	100	16	102	146
7	256 QAM	100	16	118	169
8	256 QAM	150	16	131	187

Note: Ethernet throughput depends on average packet size.

28 MHz (ETSI)

Working Point	Modulation	Minimum required capacity license	Number of Supported E1s	Ethernet Throughput	
				Min	Max
1	QPSK	50	16	38	54
2	8 PSK	50	16	53	76
3	16 QAM	100	16	75	108
4	32 QAM	100	16	103	148
5	64 QAM	150	16	127	182
6	128 QAM	150	16	156	223
7	256 QAM	150	16	167	239
8	256 QAM	200	16	185	264

Note: Ethernet throughput depends on average packet size.

30 MHz (FCC)

Working Point	Modulation	Minimum required capacity license	Number of Supported T1s	Ethernet Throughput	
				Min	Max
1	QPSK	50	16	39	55
2	8 PSK	50	16	62	89
3	16 QAM	100	16	93	133
4	32 QAM	100	16	120	171
5	64 QAM	150	16	142	202
6	128 QAM	150	16	164	235
7	256 QAM	200	16	185	264
8	256 QAM	200	16	204	292

Note: Ethernet throughput depends on average packet size.

40 MHz (ETSI)

Working Point	Modulation	Minimum required capacity license	Number of Supported E1s	Ethernet Throughput	
				Min	Max
1	QPSK	50	16	51	73
2	8 PSK	100	16	71	102
3	16 QAM	100	16	101	144
4	32 QAM	150	16	128	182
5	64 QAM	150	16	158	225
6	128 QAM	200	16	183	261
7	256 QAM	200	16	214	306
8	256 QAM	300	16	237	339

Note: Ethernet throughput depends on average packet size.

40 MHz (FCC)

Working Point	Modulation	Minimum required capacity license	Number of Supported T1s	Ethernet Throughput	
				Min	Max
1	QPSK	50	16	57	82
2	8 PSK	100	16	84	121
3	16 QAM	100	16	126	180
4	32 QAM	150	16	158	226
5	64 QAM	200	16	194	277
6	128 QAM	200	16	220	315
7	256 QAM	300	16	247	352
8	256 QAM	300	16	274	391

Note: Ethernet throughput depends on average packet size.

50 MHz (FCC)

Working Point	Modulation	Minimum required capacity license	Number of Supported T1s	Ethernet Throughput	
				Min	Max
1	QPSK	100	16	65	93
2	8 PSK	100	16	105	150
3	16 QAM	150	16	131	188
4	32 QAM	150	16	167	239
5	64 QAM	200	16	221	315
6	128 QAM	300	16	264	377
7	256 QAM	300	16	313	448
8	256 QAM	"All capacity"	16	342	489

Note: Ethernet throughput depends on average packet size.

56 MHz (ETSI)

Working Point	Modulation	Minimum required capacity license	Number of Supported E1s	Ethernet Throughput	
				Min	Max
1	QPSK	100	16	75	108
2	8 PSK	100	16	113	162
3	16 QAM	150	16	152	217
4	32 QAM	200	16	204	292
5	64 QAM	300	16	253	362
6	128 QAM	300	16	304	435
7	256 QAM	"All capacity"	16	345	493
8	256 QAM	"All capacity"	16	381	545

Note: Ethernet throughput depends on average packet size.

Transmit Power with RFU-C[1] (dBm)

Modulation	6 GHz	7-8 GHz	11-15 GHz	18 GHz	23-28 GHz	32-38 GHz
QPSK	27	26	24	22	22	19
8 PSK	27	26	24	22	22	19
16 QAM	26	25	23	21	21	18
32 QAM	25	24	22	20	20	17
64 QAM	25	24	22	20	20	17
128 QAM	25	24	22	20	20	17
256 QAM	23	22	20	18	18	15

Transmit Power with RFU-P (dBm)

Modulation	11-15 GHz	18 GHz	23-26 GHz	28-32 GHz	38 GHz
QPSK	23	23	22	21	20
8 PSK	23	23	22	21	20
16 QAM	23	21	20	20	19
32 QAM	23	21	20	20	19
64 QAM	22	20	20	19	18
128 QAM	22	20	20	19	18
256 QAM	21	19	19	18	17

Transmit Power with RFU-SP/HP[2] (dBm)

	RFU-SP	RFU-HP	
Modulation	6-8 GHz	6-8 GHz	11 GHz
QPSK	24	30	27
8 PSK	24	30	27
16 QAM	24	30	27
32 QAM	24	30	26
64 QAM	24	30	26
128 QAM	24	29	26
256 QAM	22	28	25

[1] Refer to RFU-C roll-out plan for availability of each frequency.
[2] RFU-HP supports channels with up to 30 MHz occupied bandwidth.

Receiver Threshold (RSL) with RFU-C[1] (dBm @ BER = 10^{-6})

Working point	Modulation	Channel Spacing	Occupied Bandwidth	Frequency (GHz) 6-8	11-15	18-28	32-38
1	QPSK	7 MHz (ETSI)	6.2 MHz	-92.0	-91.5	-91.0	-90.5
2	8 PSK			-89.5	-89.0	-88.5	-88.0
3	16 QAM			-86.5	-86.0	-85.5	-85.0
4	32 QAM			-84.5	-84.0	-83.5	-83.0
5	64 QAM			-82.0	-81.5	-81.0	-80.5
6	128 QAM			-79.5	-79.0	-78.5	-78.0
7	256 QAM			-76.5	-76.0	-75.5	-75.0
8	256 QAM			-74.5	-74.0	-73.5	-73.0
1	QPSK	10 MHz (FCC)	8.4 MHz	-91.0	-90.5	-90.0	-89.5
2	8 PSK			-88.5	-88.0	-87.5	-87.0
3	16 QAM			-85.0	-84.5	-84.0	-83.5
4	32 QAM			-84.0	-83.5	-83.0	-82.5
5	64 QAM			-80.0	-79.5	-79.0	-78.5
6	128 QAM			-77.0	-76.5	-76.0	-75.5
7	256 QAM			-75.5	-75.0	-74.5	-74.0
8	256 QAM			-73.0	-72.5	-72.0	-71.5
1	QPSK	14 MHz (ETSI)	12.2 MHz	-89.0	-88.5	-88.0	-87.5
2	8 PSK			-87.0	-86.5	-86.0	-85.5
3	16 QAM			-84.5	-84.0	-83.5	-83.0
4	32 QAM			-81.5	-81.0	-80.5	-80.0
5	64 QAM			-79.5	-79.0	-78.5	-78.0
6	128 QAM			-76.5	-76.0	-75.5	-75.0
7	256 QAM			-73.5	-73.0	-72.5	-72.0
8	256 QAM			-71.5	-71.0	-70.5	-70.0
1	QPSK	20 MHz (FCC)	17.4 MHz	-88.0	-87.5	-87.0	-86.5
2	8 PSK			-86.0	-85.5	-85.0	-84.5
3	16 QAM			-83.0	-82.5	-82.0	-81.5
4	32 QAM			-81.0	-80.5	-80.0	-79.5
5	64 QAM			-76.5	-76.0	-75.5	-75.0
6	128 QAM			-75.0	-74.5	-74.0	-73.5
7	256 QAM			-72.0	-71.5	-71.0	-70.5
1	QPSK	28 MHz (ETSI)	24.9 MHz	-70.0	-69.5	-69.0	-68.5
2	8 PSK			-86.5	-86.0	-85.5	-85.0
3	16 QAM			-85.0	-84.5	-84.0	-83.5
4	32 QAM			-82.0	-81.5	-81.0	-80.5
5	64 QAM			-78.5	-78.0	-77.5	-77.0
6	128 QAM			-75.5	-75.0	-74.5	-74.0
7	256 QAM			-72.0	-71.5	-71.0	-70.5
8	256 QAM			-70.5	-70.0	-69.5	-69.0

Note: RSL values are typical.

[1] Refer to RFU-C roll-out plan for availability of each frequency.

Working point	Modulation	Channel Spacing	Occupied Bandwidth	Frequency (GHz) 6-8	11-15	18-28	32-38
1	QPSK	30 MHz (FCC)	26.9 MHz	-86.5	-86.0	-85.5	-85.0
2	8 PSK			-84.0	-83.5	-83.0	-82.5
3	16 QAM			-80.5	-80.0	-79.5	-79.0
4	32 QAM			-77.5	-77.0	-76.5	-76.0
5	64 QAM			-75.0	-74.5	-74.0	-73.5
6	128 QAM			-72.5	-72.0	-71.5	-71.0
7	256 QAM			-70.0	-69.5	-69.0	-68.5
8	256 QAM			-68.0	-67.5	-67.0	-66.5
1	QPSK	40 MHz (ETSI)	31 MHz	-85.5	-85.0	-84.5	-84.0
2	8 PSK			-83.5	-83.0	-82.5	-82.0
3	16 QAM			-80.5	-80.0	-79.5	-79.0
4	32 QAM			-78.0	-77.5	-77.0	-76.5
5	64 QAM			-75.0	-74.5	-74.0	-73.5
6	128 QAM			-72.5	-72.0	-71.5	-71.0
7	256 QAM			-69.5	-69.0	-68.5	-68.0
8	256 QAM			-67.5	-67.0	-66.5	-66.0
1	QPSK	40 MHz (FCC)	35.6 MHz	-85.0	-84.5	-84.0	-83.5
2	8 PSK			-82.5	-82.0	-81.5	-81.0
3	16 QAM			-79.0	-78.5	-79.0	-78.5
4	32 QAM			-76.5	-76.0	-75.5	-75.0
5	64 QAM			-73.5	-73.0	-73.5	-73.0
6	128 QAM			-71.0	-70.5	-70.0	-69.5
7	256 QAM			-69.0	-68.5	-68.0	-67.5
8	256 QAM			-66.5	-66.0	-65.5	-65.0
1	QPSK	50 MHz (FCC)	44.3 MHz	-84.5	-84.0	-83.5	-83.0
2	8 PSK			-82.0	-81.5	-81.0	-80.5
3	16 QAM			-80.0	-79.5	-79.0	-78.5
4	32 QAM			-77.5	-77.0	-76.5	-76.0
5	64 QAM			-74.0	-73.5	-73.0	-72.5
6	128 QAM			-71.0	-70.5	-70.0	-69.5
7	256 QAM			-67.5	-67.0	-66.5	-66.0
8	256 QAM			-66.0	-65.5	-65.0	-64.5
1	QPSK	56 MHz (ETSI)	49.1 MHz	-84.0	-83.5	-83.0	-82.5
2	8 PSK			-81.5	-81.0	-80.5	-80.0
3	16 QAM			-79.5	-79.0	-78.5	-78.0
4	32 QAM			-76.0	-75.5	-75.0	-74.5
5	64 QAM			-73.0	-72.5	-72.0	-71.5
6	128 QAM			-70.0	-69.5	-69.0	-68.5
7	256 QAM			-67.5	-67.0	-66.5	-66.0
8	256 QAM			-65.5	-65.0	-64.5	-64.0

Note: RSL values are typical.

Receiver Threshold (RSL) with RFU-P (dBm @ BER = 10^{-6})

Working point	Modulation	Channel Spacing	Occupied Bandwidth	Frequency (GHz) 11-18	23-28	31	32-38
1	QPSK	10 MHz (FCC)	8.4 MHz	-91.0	-90.5	-90.5	-89.5
2	8 PSK			-88.5	-88.0	-88.0	-87.0
3	16 QAM			-85.0	-84.5	-84.5	-83.5
4	32 QAM			-84.0	-83.5	-83.5	-82.5
5	64 QAM			-80.0	-79.5	-79.5	-78.5
6	128 QAM			-77.0	-76.5	-76.5	-75.5
7	256 QAM			-75.5	-75.0	-75.0	-74.0
8	256 QAM			-73.0	-72.5	-72.5	-71.5
1	QPSK	14 MHz (ETSI)	12.2 MHz	-89.0	-88.5	-88.5	-87.5
2	8 PSK			-87.0	-86.5	-86.5	-85.5
3	16 QAM			-84.5	-84.0	-84.0	-83.0
4	32 QAM			-81.5	-81.0	-81.0	-80.0
5	64 QAM			-79.5	-79.0	-79.0	-78.0
6	128 QAM			-76.5	-76.0	-76.0	-75.0
7	256 QAM			-73.5	-73.0	-73.0	-72.0
8	256 QAM			-71.5	-71.0	-71.0	-70.0
1	QPSK	20 MHz (FCC)	17.4 MHz	-88.0	-87.5	-87.5	-86.5
2	8 PSK			-86.0	-85.5	-85.5	-84.5
3	16 QAM			-83.0	-82.5	-82.5	-81.5
4	32 QAM			-81.0	-80.5	-80.5	-79.5
5	64 QAM			-76.5	-76.0	-76.0	-75.0
6	128 QAM			-75.0	-74.5	-74.5	-73.5
7	256 QAM			-72.0	-71.5	-71.5	-70.5
8	256 QAM			-70.0	-69.5	-69.5	-68.5
1	QPSK	28 MHz (ETSI)	24.9 MHz	-86.5	-86.0	-86.0	-85.0
2	8 PSK			-85.0	-84.5	-84.5	-83.5
3	16 QAM			-82.0	-81.5	-81.5	-80.5
4	32 QAM			-78.5	-78.0	-78.0	-77.0
5	64 QAM			-75.5	-75.0	-75.0	-74.0
6	128 QAM			-72.0	-71.5	-71.5	-70.5
7	256 QAM			-70.5	-70.0	-70.0	-69.0
8	256 QAM			-68.0	-67.5	-67.5	-66.5

Note: RSL values are typical.

Working point	Modulation	Channel Spacing	Occupied Bandwidth	Frequency (GHz)			
				11-18	23-28	31	32-38
1	QPSK	30 MHz (FCC)	26.9 MHz	-86.5	-86.0	-86.0	-85.0
2	8 PSK			-84.0	-83.5	-83.5	-82.5
3	16 QAM			-80.5	-80.0	-80.0	-79.0
4	32 QAM			-77.5	-77.0	-77.0	-76.0
5	64 QAM			-75.0	-74.5	-74.5	-73.5
6	128 QAM			-72.5	-72.0	-72.0	-71.0
7	256 QAM			-70.0	-69.5	-69.5	-68.5
8	256 QAM			-68.0	-67.5	-67.5	-66.5
1	QPSK	40 MHz (ETSI)	31 MHz	-85.5	-85.0	-85.0	-84.0
2	8 PSK			-83.5	-83.0	-83.0	-82.0
3	16 QAM			-80.5	-80.0	-80.0	-79.0
4	32 QAM			-78.0	-77.5	-77.5	-76.5
5	64 QAM			-75.0	-74.5	-74.5	-73.5
6	128 QAM			-72.5	-72.0	-72.0	-71.0
7	256 QAM			-69.5	-69.0	-69.0	-68.0
8	256 QAM			-67.5	-67.0	-67.0	-66.0
1	QPSK	40 MHz (FCC)	35.6 MHz	-85.0	-84.5	-84.5	-83.5
2	8 PSK			-82.5	-82.0	-82.0	-81.3
3	16 QAM			-79.0	-78.5	-78.5	-77.5
4	32 QAM			-76.5	-76.0	-76.0	-75.0
5	64 QAM			-73.5	-73.0	-73.0	-72.0
6	128 QAM			-71.0	-70.5	-70.5	-69.5
7	256 QAM			-69.0	-68.5	-68.5	-67.5
8	256 QAM			-66.5	-66.0	-66.0	-65.0
1	QPSK	50 MHz (FCC)	44.3 MHz	-84.5	-84.0	-84.0	-83.0
2	8 PSK			-82.0	-81.5	-81.5	-80.5
3	16 QAM			-80.0	-79.5	-79.5	-78.5
4	32 QAM			-77.5	-77.0	-77.0	-76.0
5	64 QAM			-74.0	-73.5	-73.5	-72.5
6	128 QAM			-71.0	-70.5	-70.5	-69.5
7	256 QAM			-67.5	-67.0	-67.0	-66.0
8	256 QAM			-66.0	-65.5	-65.5	-64.5
1	QPSK	56 MHz (ETSI)	49.1 MHz	-84.0	-83.5	-83.5	-82.5
2	8 PSK			-81.5	-81.0	-81.0	-80.0
3	16 QAM			-79.5	-79.0	-79.0	-78.0
4	32 QAM			-76.0	-75.5	-75.5	-74.5
5	64 QAM			-73.0	-72.5	-72.5	-71.5
6	128 QAM			-70.0	-69.5	-69.5	-68.5
7	256 QAM			-67.5	-67.0	-67.0	-66.0
8	256 QAM			-65.5	-65.0	-65.0	-64.0

Note: RSL values are typical.

Receiver Threshold (RSL) with RFU-SP/HP[1] (dBm @ BER = 10^{-6})

Working point	Modulation	Channel Spacing	Occupied Bandwidth	RFU-SP (6-8 GHz)	RFU-HP (6-11 GHz)
1	QPSK	10 MHz (FCC)	8.4 MHz	-91.5	-91.5
2	8 PSK			-89.0	-89.0
3	16 QAM			-85.5	-85.5
4	32 QAM			-84.5	-84.5
5	64 QAM			-80.5	-80.5
6	128 QAM			-77.5	-77.5
7	256 QAM			-76.0	-76.0
8	256 QAM			-73.5	-73.5
1	QPSK	14 MHz (ETSI)	12.2 MHz	-89.5	-89.5
2	8 PSK			-87.5	-87.5
3	16 QAM			-85.0	-85.0
4	32 QAM			-82.0	-82.0
5	64 QAM			-80.0	-80.0
6	128 QAM			-77.0	-77.0
7	256 QAM			-74.0	-74.0
8	256 QAM			-72.0	-72.0
1	QPSK	20 MHz (FCC)	17.4 MHz	-88.5	-88.5
2	8 PSK			-86.5	-86.5
3	16 QAM			-83.5	-83.5
4	32 QAM			-81.5	-81.5
5	64 QAM			-77.0	-77.0
6	128 QAM			-75.5	-75.5
7	256 QAM			-72.5	-72.5
8	256 QAM			-70.5	-70.5
1	QPSK	28 MHz (ETSI)	24.9 MHz	-87.0	-87.0
2	8 PSK			-85.5	-85.5
3	16 QAM			-82.5	-82.5
4	32 QAM			-79.0	-79.0
5	64 QAM			-76.0	-76.0
6	128 QAM			-72.5	-72.5
7	256 QAM			-71.0	-71.0
8	256 QAM			-68.5	-68.5

Note: RSL values are typical.

[1] RFU-HP supports channels with up to 30 MHz occupied bandwidth.

Working point	Modulation	Channel Spacing	Occupied Bandwidth	RFU-SP (6-8 GHz)	RFU-HP (6-11 GHz)
1	QPSK	30 MHz (FCC)	26.9 MHz	-87.0	-87.0
2	8 PSK			-84.5	-84.5
3	16 QAM			-81.0	-81.0
4	32 QAM			-78.0	-78.0
5	64 QAM			-75.5	-75.5
6	128 QAM			-73.0	-73.0
7	256 QAM			-70.5	-70.5
8	256 QAM			-68.5	-68.5
1	QPSK	40 MHz (ETSI)	31 MHz	-86.0	Not supported
2	8 PSK			-84.0	Not supported
3	16 QAM			-81.0	Not supported
4	32 QAM			-78.5	Not supported
5	64 QAM			-75.5	Not supported
6	128 QAM			-73.0	Not supported
7	256 QAM			-70.0	Not supported
8	256 QAM			-68.0	Not supported
1	QPSK	40 MHz (FCC)	35.6 MHz	-85.5	Not supported
2	8 PSK			-83.0	Not supported
3	16 QAM			-79.5	Not supported
4	32 QAM			-77.0	Not supported
5	64 QAM			-74.0	Not supported
6	128 QAM			-71.5	Not supported
7	256 QAM			-69.5	Not supported
8	256 QAM			-67.0	Not supported
1	QPSK	50 MHz (FCC)	44.3 MHz	-85.0	Not supported
2	8 PSK			-82.5	Not supported
3	16 QAM			-80.5	Not supported
4	32 QAM			-78.0	Not supported
5	64 QAM			-74.5	Not supported
6	128 QAM			-71.5	Not supported
7	256 QAM			-68.0	Not supported
8	256 QAM			-66.5	Not supported
1	QPSK	56 MHz (ETSI)	49.1 MHz	-84.5	Not supported
2	8 PSK			-82.0	Not supported
3	16 QAM			-80.0	Not supported
4	32 QAM			-76.5	Not supported
5	64 QAM			-73.5	Not supported
6	128 QAM			-70.5	Not supported
7	256 QAM			-68.0	Not supported
8	256 QAM			-66.0	Not supported

Note: RSL values are typical.

Interfaces

Ethernet

Supported Ethernet interfaces	5 x 10/100base-T (RJ45) 1 x 10/100/1000Base-T (RJ45) 1 x 1000base-X (SFP)
Supported SFP types	1000Base-LX (1310 nm) or SX (850 nm) or 1000base-T
Latency over the radio link	< 0.15mSeconds @ 400 Mbps
"Baby jumbo" frames support	Up to 1632Bytes
Supported Ethernet/IP standards	802.3 – 10base-T 802.3u – 100base-T 802.3ab – 1000base-T 802.3z – 1000base-X 802.3ac – Ethernet VLANs 802.1Q – Virtual LAN (VLAN) 802.1p – Class of service 802.1ad – Provider bridges (QinQ) 802.3x – Flow control 802.3ad – Link aggregation 802.1ag/Y.1731 – Ethernet network OA&M 802.3ah – Ethernet link OA&M 802.1D – STP 802.1w – RSTP 802.1s – MSTP RFC 1349 – IPv4 TOS RFC 2474 – IPv4 DSCP RFC 2460 – IPv6 Traffic Classes
MEF certification	MEF-9 & MEF-14 certified for all service types (EPL, EVPL & E-LAN) 

E1/T1

Interface Type	E1/T1
Number of ports	16 per unit (optional)
Connector Type	MDR 69-pin
Framing	Unframed (full transparency)
Coding	E1: HDB3 T1: AMI/B8ZS
Line Impedance	120 ohm/100 ohm balanced. Optional 75 ohm unbalanced.
Compatible Standards	ITU-T G.703, G.736, G.775, G.823, G.824, G.828, ITU-T I.432, ETSI ETS 300 147, ETS 300 417, ANSI T1.105, T1.102-1993, T1.231, Bellcore GR-253-core, TR-NWT-000499

Auxiliary Channels

Wayside Channel	2 Mbps or 64 Kbps, Ethernet 10/100BaseT
Engineering Order Wire	Audio channel (64 Kbps) G.711
User Channel	Asynchronous V.11/RS-232 up 19.2 kbps

Network Management, Diagnostics, Status, and Alarms

Management	PolyView NMS, Web based EMS & CLI support
Protocols	SNMPv1/v2 for NMS - in compliance with RFC 1213 HTTP for web EMS Telnet FTP
Management Interface	Dedicated Ethernet interfaces (up to 3) or in-band
Local Configuration and Monitoring	Standard ASCII terminal, serial RS-232
In-Band Management	Support dedicated VLAN for management
TMN	Ceragon NMS functions are in accordance with ITU-T recommendations for TMN
External Alarms	4 Inputs: TTL-level or contact closure to ground. 1 output: Form C contact, software configurable.
RSL Indication	Accurate power reading (dBm) available at IDU, RFU[1], and NMS
Performance Monitoring	Integral with onboard memory per ITU-T G.826/G.828

[1] Note that the voltage at the BNC port on the RFUs is not accurate and should be used only as an aid

Mechanical

Dimensions	Height: 42.6 mm (1RU) Width: 439 mm (<19") Depth: 188 mm, without mounting ears and connectors
Weight	2.5 kg/5.4 lbs

Environment

Operating Temperature (Guaranteed Performance)	RFU: -35°C to 55°C IDU: 5°C to 55°C
Relative Humidity	RFU: up to 100% (all weather operation) IDU: up to 85% (non-condensing)
Altitude	Up to 4,500 m (15,000 ft)
Office Vibration	0.1g at 5-200 Hz

Power Input

Standard Input	-48 VDC
DC Input range	-40.5 to -59 VDC (up to -57 VDC for USA market)
Optional Inputs	110-220 VAC -24 VDC

Power Consumption

Max power consumption IP-10 IDU	25W
Max system power consumption RFU-C + IP-10	1+0 with RFU-C 6-26 GHz: 47W 1+0 with RFU-C 28-38 GHz: 51W 1+1 with RFU-C 6-26 GHz: 84W 1+1 with RFU-C 28-38 GHz: 88W
Max system power consumption RFU-P + IP-10	1+0: 65W 1+1: 105W
Max system power consumption RFU-SP + IP-10	1+0: 80W 1+1: 130W
Max system power consumption RFU-HP + IP-10	1+0: 105W 1+1: 150W