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PROVISIONAL APPLICATION COVER SHEET

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Inventors/Applicants

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TITLE OF THE INVENTION

USING CABLE MODEMS FOR CATV NETWORK MONITORING

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Customer No: 44362

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Please associate this application with Customer No: 44362

Respectfully submitted,

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February 18, 2011
Date:

/mdb

Using Cable Modems for CATV Network Monitoring

DOCSIS 3.0 compliant cable modems provide multiple downstream receivers and upstream transmitters. They have the ability to bond up to 8 channels in the downstream and 4 channels in the upstream so as to achieve high data transfer rates. Future versions of DOCSIS will require that cable modems bond an increasing number downstream and upstream channels.

Subscriber data services do not need to use all the transmitters or receivers at all times. Some DOCSIS modems are capable of performing signal level, channel scans, hum, and digital quality measurements on any or all downstream channels of the cable plant using one or more of their downstream receivers. They can also transmit test signals to other equipment on the network using one or more of their upstream transmitters in order to perform sweep tests. These modems can perform these tests while continuing to provide data services for the subscriber with the remaining transmitters and receivers.

Additionally, the transmitters and receivers actively used in the DOCSIS connection could also be used to perform both active and passive network service tests to measure the DOCSIS connection characteristics. These tests are designed to have negligible impact upon the customer's use of the DOCSIS connection.

In the preferred embodiment of this invention, subscriber modems are configured with software providing these extra measurement capabilities. This enables cable operators to add network monitoring and diagnostic services without installing extra equipment at subscriber premises. Alternatively, subscriber modems may contain extra circuitry in order to provide measurement capabilities. This extra software would run along side the main cable modem software, either on the same processor, a co-processor, or another processor somewhere within the cable modem that still has access to all necessary hardware control functions.

This invention consists of one or more of these measurement-capable cable modems (MCCM) being directed by remote control from a central measurement controller (CMC) or a local measurement controller (LMC) to perform a variety of signal-level measurements that previously required a dedicated measurement instrument. Optionally when required, the CMC communicates with the Cable Modem Termination System (CMTS) to request that it exclude one or more receivers and/or transmitters from DOCSIS channel bonding. Then the CMC signals the MCCM via internet protocol messaging to perform specific measurements with the unused receivers and/or transmitters. The DOCSIS connection would provide the necessary communication path for the CMC to direct the MCCM as to which measurement to perform.

In addition to the CMC, the MCCM could be controlled by a local measurement controller. In this case, specialized software residing upon a portable computing platform would be used to issue commands to the MCCM through a local or physical connection to the CM. A USB or LAN connection might be one example of a local connection to the MCCM. This functionality allows a technician to use the MCCM measurement capabilities when there is a problem that prevents the DOCSIS channel from successful operation.

In order to ensure security within the network, the MCCM authenticates that all commands come from a trusted source before acting upon them. A trusted source may reside on the WAN, LAN, or be connected to the CM in some other manner and must have the proper security credentials. It also rejects any commands that conflict with its configured operation as a DOCSIS cable modem.

The MCCM would have the ability to perform the following measurements:

- Analog measurements such as Level, Carrier-to-Noise, Hum

- Digital measurements such as Level, MER, Pre- and Post- Forward Error Correction (FEC) Bit Error Rate (BER), DQI (Digital Quality Index, defined in US Patent 7,792,183), Errored Seconds, Constellation, and Ingress under the carrier.
- Combined scan style measurements: all channel levels, a subset of channel levels, and all digital channel MER values.
- Spectrum analyzer style measurements that print a graph of the raw level of the network as a function of frequency.
- Both forward and reverse sweep measurements. These could be coordinated across several MCCMs so that the reference taken by one MCCM near the headend is used as the reference for the rest of the MCCMs in the network. This would allow the CMC to draw conclusions about the frequency response of the network.
- Other JDSU proprietary and patented measurement algorithms.

The CMC can be configured to monitor various measurement results from across the entire downstream spectrum at any or all subscriber locations equipped with MCCMs. The CMC can do any of the following:

- Store historical data for trending
- Generate alarms when signal degradation is detected anywhere within the network
- Determine the portion of the network affected by the degradation
- Adjust its monitoring schedule based on network conditions, time of day, or requests from users or from other test or monitoring equipment.

Summary of differences from patent by Kamieniecki

1. The set-top box can only measure while it is in an idle state. This invention would allow the measurements to be taken while the CM is actively being used for communication by a subscriber.
2. The set-top box requires an out of band communication channel. This invention uses the DOCSIS upstream and downstream, or a local LAN directly connected to the CM.
3. The set-top box must have 2 tuners. Current technology kind of makes this obsolete because now there are wide band tuners available that allow you to do all of this with one tuner. This invention dodges the issue of number of tuners and instead mentions that we would use existing CM hardware receivers/demodulators and transmitters for measurement.
4. Paragraph [0027] mentions that other methods could be used for sending signal quality reports. This could be a problem if it includes DOCSIS as a communication channel.
5. The patent app only mentions channel level measurements.

First and foremost, that '879 patent only describes a STB-based monitoring solution, whereas we would be looking first at a D3 cable modem-based monitoring solution.

Next, as you point out, although the STB technically has two tuners, one of them is an "out-of-band tuner" which typically can only tune up to 150 MHz or so. That's of course why they require the STB be idle in order to perform the measurements. I would not downplay the discrepancy here; since the '879 patent explicitly specified one of the tuners to be an out-of-band tuner (Claim 28) which were/are known to have a limited frequency range and measurement bandwidth.

Other things they did not claim (just thinking out loud here):

- 1) Commanding a particular CPE device remotely to start a measurement session on demand (not a monitoring application, per se)
- 2) Monitoring using the CPE but sending the results somewhere other than the head end (where, I don't know...)
- 3) Monitoring using measurements by the CPE of signals it is transmitting, versus receiving (i.e. DOCSIS or OOB Tx level)
- 4) Monitoring CPE health by collecting other status or error codes from the device (i.e. hardware failures, error logs/conditions, physical interface errors/conditions)

5) Collecting "raw" data from the CPE which is not "information about" signals received, but the signals themselves (i.e. ADC capture data). This is a nit-picky distinction and have no idea if it would pass muster.

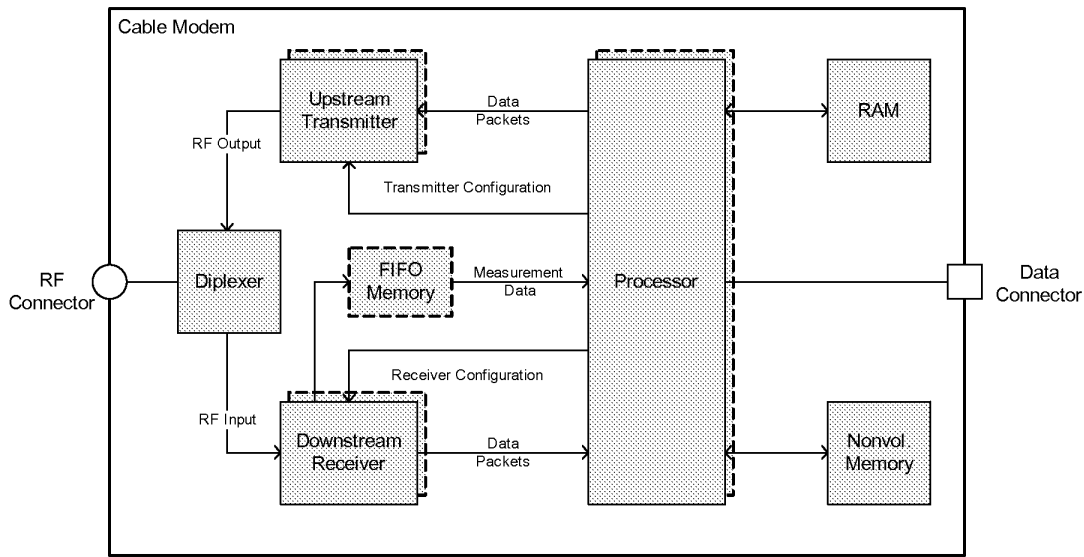


Fig. 1

Cable Modem Block Diagram Description

Cable Modem (Fig. 1):

A cable modem is a device that transforms digital data transmitted over RF to one or more interfaces (Ethernet, USB, etc...). DOCSIS 3.0 compliant modems will typically have the following items, either physically through dedicated hardware, or logically through more generic hardware with dedicated software. Items in the diagram that have a solid border are required for this invention. Items that have a dashed-line border are optional hardware for this invention that could improve the effectiveness of the invention, depending upon the features and capabilities of the cable modem platform upon which this invention is constructed.

Duplexer:

This device is responsible for splitting the RF spectrum into an upstream and downstream. Data that is sent to the cable modem is transmitted in the downstream spectrum. The cable modem transmits data to the CMTS in the upstream spectrum. Since this invention requires that the cable modem continue to be operational for the end user, the invention would not permit measuring in the upstream spectrum.

Upstream Transmitter:

A DOCSIS 3.0 compliant modem will have the ability to transmit at multiple frequencies. If a transmitter is not currently being used by the CM for data transmit, it can be used to perform sweep style measurements to the headend. The measurement program would have the ability to configure the transmitters for various types of transmissions so as to perform upstream tests. Use of spare upstream transmitters would facilitate tests including the following:

- Upstream frequency response
- Ingress/Impulse detection

Processor:

The CM will have at least one processor that runs the software program responsible for all cable modem activities. The measurement program could reside on the same processor and run as separate tasks

within the main CM software program, or it could be a separate measurement program that runs on a co-processor that resides somewhere within the CM.

RAM:

The CM has memory available to the processor or co-processors. Any portion of this memory that the CM software is not using may be used by the measurement software to store data, intermediate calculations, and measurement results ready to be sent to the CMC or LMC.

Non-volatile Memory:

The CM has non-volatile memory that is used to store both the CM software program and the measurement software program when the modem is not powered. Measurement data from various supported tests could also be saved in non-volatile memory for later access or query by CMC or LMC.

FIFO Memory:

The measurement system may require the addition of FIFO memory if the CM's processor and bus architecture are not capable of capturing the measurement data at the required sampling rates. The various components of the receiver can stream data to the FIFO at high rates during the actual measurement and the processor can read the data at a slower rate to post-process the results.

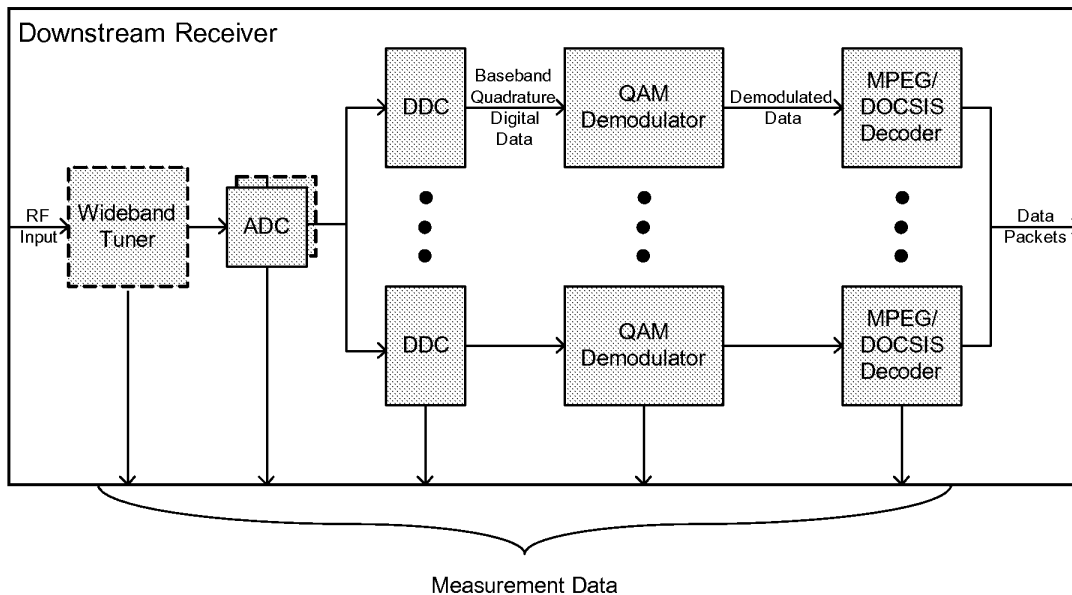


Fig. 2

Downstream Receiver (Fig. 2):

The CM has one or more downstream receivers, each capable of demodulating one or more downstream channels. Note that DOCSIS 3.0 currently specifies that up to eight downstreams could be present as the bonded DOCSIS channel group and that as we go forward with future DOCSIS specifications, it looks like the number of bonded channels will only increase. A DOCSIS 3.0 downstream receiver is typically made up of the following components:

Wideband Tuner:

The wideband tuner allows the CM to tune to a group of channels. Depending on the implementation, a tuner's bandwidth could be as narrow as 6 MHz or as wide as 1 GHz. The input into the tuner is analog RF data from the diplexer cutoff frequency to approximately 1 GHz. It converts RF signals at a band of frequencies to corresponding frequencies centered at an intermediate frequency (IF). A tuner is optional

because all tuning processes can be performed purely digitally using one or more ADCs and DDCs. The tuner could be queried or use the FIFO to gather data for the following measurements:

- Level
- Spectrum style measurements
- Downstream frequency response

ADC (Analog to Digital Converter):

The CM would have one or more ADCs connected to the output of the wideband tuner. The ADC is responsible for transforming the analog intermediate frequency (IF) output from the wideband tuner and converting it into digitized IF data. The ADC allows for measuring level and spectrum style measurements within the frequency span covered by the analog IF input. Depending on the CM processor and ADC speeds, raw data from the ADC combined with specialized software could allow for all measurements that are enabled by hardware blocks later in the pipeline.

DDC (Digital Down-Converter):

The DDC is responsible for filtering out a 6 or 8 MHz wide channel that is covered by the digital IF output from the ADC(s). A DDC converts a digitized real signal centered at an intermediate frequency to a basebanded complex signal centered at a zero frequency. The input to this block is digital IF data from the ADC which typically covers the entire frequency span of the wideband tuner and the output of the block is I/Q samples for a particular channel within the wideband frequency span. A DOCSIS 3.0 CM will typically have four to eight DDCs per downstream receiver. However, this number is expected to increase as technology improves. Any extra unused DDCs can be used to perform measurements such as:

- Analog or digital channel level
- Downstream frequency response

These measurements can be done here, but if CM hardware permits, the preferred method would be to do them with the QAM demodulator:

- I/Q Constellation plots
- Ingress under the carrier

QAM Demodulator:

The QAM demodulator in a CM is responsible for demodulating an individual digital channel so that I/Q samples are converted into digital data. Any extra unused QAM Demodulators can be used to perform measurements such as:

- MER
- EQ Stress
- Group Delay
- In-channel frequency response

Depending on the CM hardware, the demodulator may also provide these measurements:

- I/Q Constellation plots
- Ingress under the carrier
- DQI

MPEG/DOCSIS Decoder:

After the RF signal has been transformed from wideband RF data to individual digital channel data, the data is decoded by an MPEG or DOCSIS decoder. The measurement program on the CM can be used to perform a variety of service level tests.

MPEG and DOCSIS decoders have rate counters and packet error counters that can be used to perform the following measurements on each channel:

- Pre and Post Bit Error Rate (BER)
- MPEG data stream errors.

Additionally, MPEG and DOCSIS decoders that are being used as part of the active DOCSIS connection can be used to passively perform a downstream throughput measurement on each downstream channel.

MPEG and DOCSIS decoders that are being used as part of the active DOCSIS connection can also be used to perform active tests without negatively impacting the customer's network connection. The measurement program on the CM can be used to generate data traffic that enables the following measurements:

- Upstream and Downstream Throughput
- Network connectivity checks (ping).
- Packet loss
- VoIPCheck™
- Jitter

**CM Network Monitor
Flow Chart Descriptions
and
Extra Implementation Information**

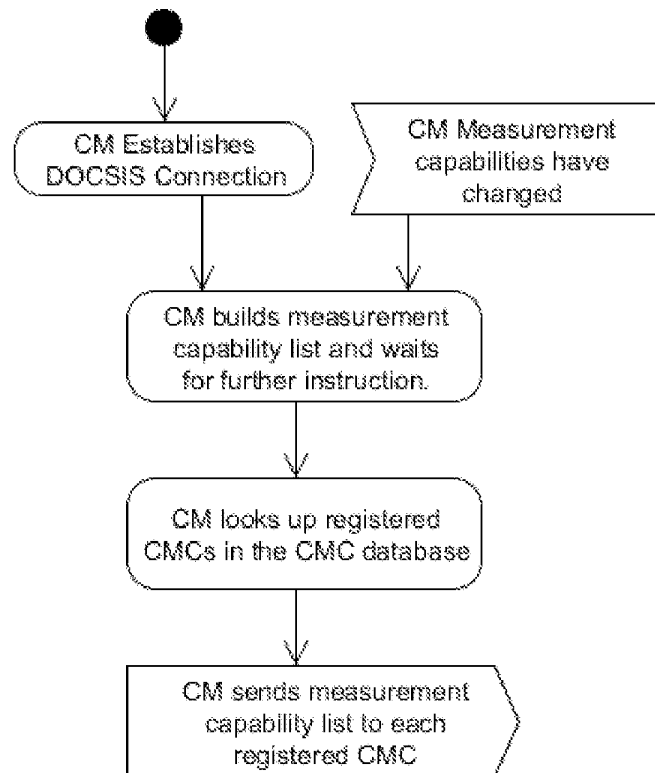


Figure 1: CM builds Measurement Capability List

The above diagram shows one possible set of steps that a cable modem would use to build its measurement capability list. There are two possible events that would cause the cable modem to build a new measurement capability list. The first would be if the modem is booted and then successfully establishes a DOCSIS connection. The second is if the cable modem's measurement capabilities have changed, for example when the CMTS orders the cable modem to change its bonding group as part of a load balancing operation.

Once the cable modem determines that it needs to build a measurement capability list, it will examine its hardware and software configuration to determine how many downstream receivers and upstream transmitters are idle (not being actively used by the established DOCSIS connection). Provided there are resources available, the cable modem would then examine its measurement software configuration to determine which measurements could be supported given the available resources. The modem would then compile this list together and send it to all registered central measurement controllers (CMC).

After it has sent the measurement capability list to the CMCs, the modem would wait for a measurement plan from the CMC. Alternatively, the cable modem might have a previously saved measurement plan. In this case the cable modem would set a timer for when to start that measurement plan.

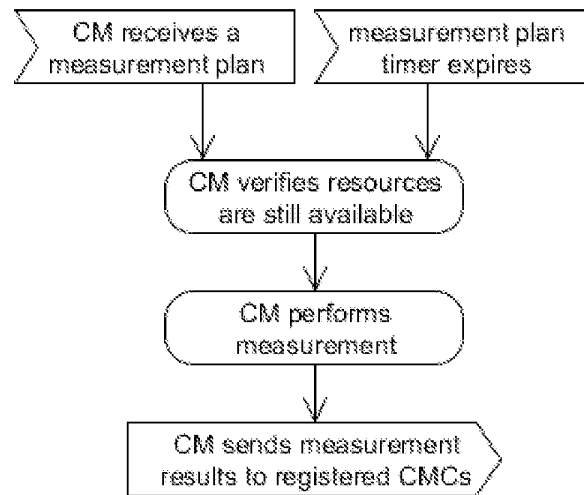


Figure 2: Cable Modem performs a measurement

The above diagram outlines the steps necessary for a cable modem to perform a measurement. A cable modem would perform a measurement whenever receives a new measurement plan from the CMC or whenever its measurement plan timer expires. Once the cable modem has determined that it needs to start a measurement, it will verify that the resources necessary are still available. If they are not available, the cable modem will not perform the measurement. However, provided that they are available, the cable modem will then step through the measurement plan and perform the requested measurements according to the provided plan parameters. Upon completion of the measurement plan, the cable modem will send the results to the CMC.

After sending the measurement results to the CMC, the CM Measurement application will wait for the measurement timer to expire, for the reception of a new measurement plan, or for the measurement capabilities to change.

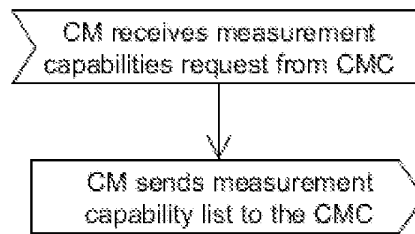


Figure 3: Get cable modem measurement capability list

The CMC or LMC can request the measurement capability list from the cable modem at any time so they can generate a new measurement plan. This diagram shows that when a cable modem receives a request to get its measurement capability list, the cable modem will send its measurement capability list to the requestor.

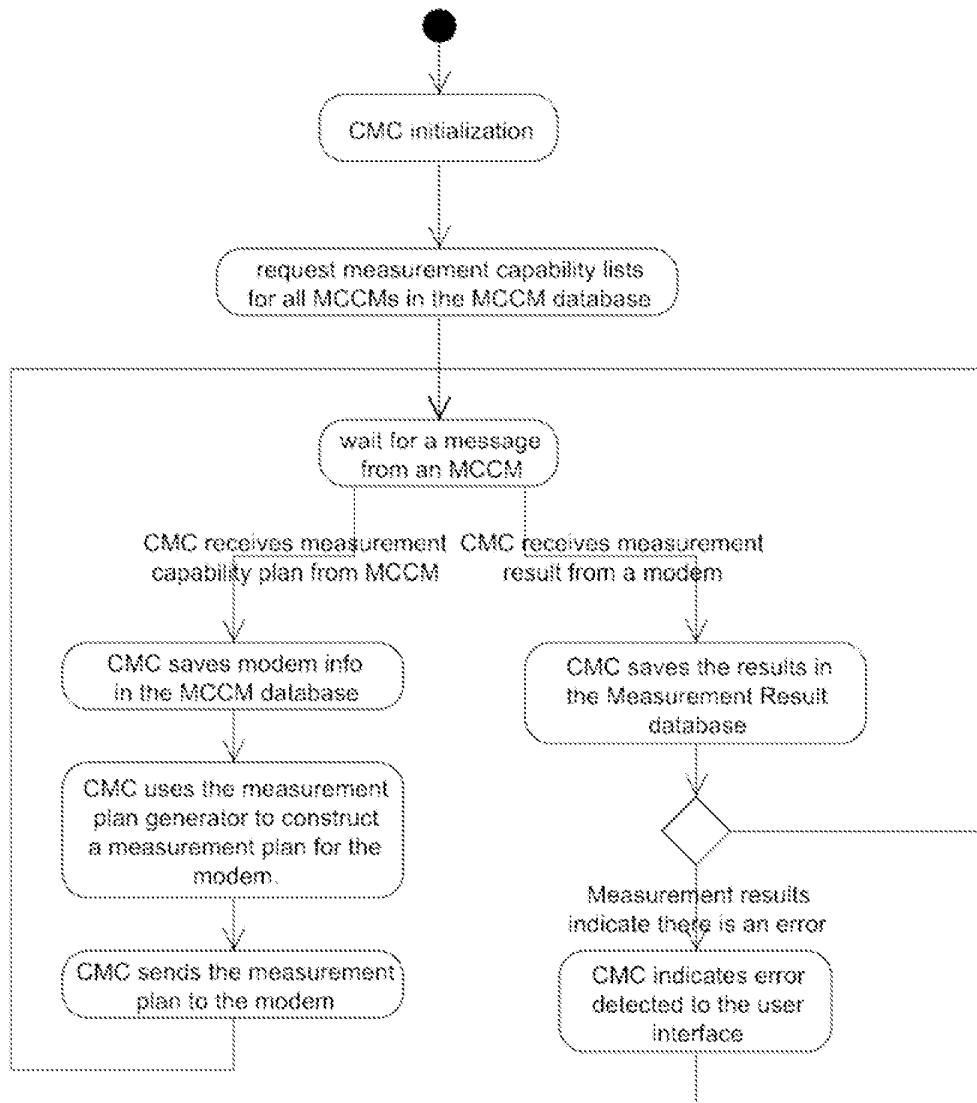


Figure 4: CMC flow

This diagram displays one possible control flow for the CMC. The CMC will startup and perform initialization activities. Upon completion of initialization, the CMC could send a request to get the measurement capability list for each MCCM in the MCCM data base. The CMC would then wait for a message from the MCCM.

If the CMC receives a measurement capability list from an MCCM, the CMC would perform the following steps:

1. Add the MCCM to the MCCM data base, if necessary
2. Use the received measurement capability list and measurement plan generator to construct a measurement plan for the cable modem.
3. Send the measurement plan to the cable modem.

If the CMC receives a measurement result from the cable modem, the CMC could perform the following steps:

1. Save the results in the measurement result database. This would allow the data to be queried at a later date to look for trends or changes in the test results that might help indicate a network error.

2. Parse the measurement results to determine if a network error has been detected. If a problem has been detected, the CMC could indicate this problem to the user.

One Possible Sequence of Events (slightly more detailed)

1. Central Measurement Controller (CMC) starts up and is initialized.
 - a. A user configures the channel plan.
 - b. A user configures which tests they would like to run for a given set of modem measurement capabilities. This sets up the Measurement Capability Database and Measurement Plan Generator.
 - c. Suppose for sake of example that on the very first initialization, the MCCM Database is empty, so the MCCM skips sending any requests to the cable modems to get their measurement capabilities.
2. Somewhere in the system, an MCCM is powered on and successfully establishes a DOCSIS connection with the CMTS. The CMTS orders the cable modem to establish a DOCSIS connection such that the MCCM has extra resources available for measurement.
3. The MCCM figures out how many Downstream Receivers and Upstream Transmitters are available for use by measurement algorithms. Based on this, the hardware present, and measurement software present, the MCCM builds up its measurement capability list and sends it to a registered CMC.
4. The CMC receives the measurement capability list from the cable modem and performs the following:
 - a. Adds the modem to the MCCM database.
 - b. Generates a measurement plan that should be run on this cable modem given the provided measurement capability list.
 - c. Sends the measurement plan to the cable modem.
5. The MCCM receives the measurement plan and performs the following:
 - a. The MCCM performs the measurement according to the parameters outlined in the measurement plan.
 - b. Upon measurement plan completion, the MCCM sends results to the CMC and sets a timer for when to perform the measurement plan again, as specified by the measurement plan.
 - c. Upon expiration of the timer, the MCCM will repeat these three steps.
6. The CMC receives the measurement results from the MCCM and inserts them into the measurement result database. The results are further parsed to determine if there is a condition that indicates a network error in the system.

Steps necessary to build up the measurement capability list:

1. The cable modem examines its hardware configuration to determine how many downstream receivers are not being used. If at least one downstream receiver is idle, then the cable modem has resources available for measurement of non-DOCSIS downstream channels.
2. The cable modem examines its hardware configuration to determine how many upstream transmitters are not being used. If at least one upstream transmitter is idle, then the cable modem has resources available for transmitting test signals in the upstream frequency band.
3. The cable modem examines its software configuration to figure out which measurement capabilities it can support given the set of available downstream receivers and transmitters. Measurement capabilities could be divided into the following categories:
 - a. **Service Level Test Capabilities** – These measurement capabilities are available whenever the cable modem has successfully established a DOCSIS connection with the CMTS. The modem does not need any idle downstream receivers or upstream transmitters to support these capabilities:
 - i. Downstream throughput measurement
 - ii. Upstream throughput measurement
 - iii. VoIPCheck
 - iv. Upstream Packet loss
 - v. Downstream Packet loss
 - vi. Network connectivity (ping).
 - b. **Analog Measurement Capabilities** – These measurement capabilities are available if at least one downstream receiver is idle and if the cable modem hardware and measurement software can support the necessary requirements to accomplish them.
 - i. Level measurement
 - ii. Hum
 - iii. Carrier to Noise
 - c. **Analog Signal Type Capabilities** – These capabilities indicate what type of analog signals can be measured by the cable modem. Some, but not all examples include:
 - i. Supported Analog signals (e.g. Analog TV with single audio carrier, Analog TV with dual audio carrier, Scrambled Analog TV, SECAM, Carrier wave, etc...)
 - ii. Supported frequency ranges (e.g. 85 – 1000 MHz)
 - d. **Digital Measurement Capabilities** – These measurement capabilities are available if at least one downstream receiver is idle and if the cable modem hardware and measurement software can support the necessary requirements to accomplish them.
 - i. Digital level
 - ii. MER
 - iii. Bit error rates
 - iv. Digital Quality Index
 - v. Ingress under the carrier
 - vi. IQ sampling
 - vii. Errored Seconds
 - e. **Digital Signal Type Capabilities** – These capabilities indicate what types of digital signals can be measured by the cable modem.
 - i. Deep interleave (forward error correction interleaver depth greater than 128,1)
 - ii. Supported QAM signal type (QAM 64, 128, 256, etc...)
 - iii. Supported Annex signal type (Annex A, Annex B, etc...)
 - iv. Supported frequency ranges (e.g. 85 – 1000 MHz)
 - f. **Transmit Capabilities** – These capabilities indicate what types of signals could be transmitted by the cable modem for use during upstream measurement tests.
 - i. Carrier wave
 - ii. QAM (16, 32, 64, etc...)
 - iii. Supported frequency ranges (e.g. 5 – 85 MHz)
4. Once the MCCM has constructed its measurement capability list, it sends it to the CMC so that the CMC can generate an appropriate measurement plan for the modem.

The above approach using measurement capability lists was given as an example because it shows how this invention could work if there are a variety of cable modems in the system. Note that one cable modem would likely not have the same measurement capabilities as another produced by a different vendor.

Note that using a measurement capability list is not the only implementation for this invention. Instead of using measurement capability lists, the CMC could construct an arbitrary measurement plan and send it to all or some MCCMs in the network. It would then be up to the MCCMs to verify that they have the required resources available to perform the requested measurement before actually performing the measurement. Some level of resource availability verification would probably always need to be run on the MCCM because at any time the CMTS could change the channel bonding group for load balancing activities. It is important to note that this invention should not negatively impact the customer's use of the cable modem as a communication device.

Some things enabled by this invention that do not exist in prior art:

1. An MCCM could detect that there is a problem with a non-DOCSIS channel within the customer premise. This problem could be addressed before the customer has a chance to complain about it.
2. Multiple MCCMs working together, as directed by the CMC, could detect that there is a problem with one or more non-DOCSIS channels in one part of the cable network. This would allow technicians to diagnose problems with network equipment outside a customer premise. The problem could be addressed before a customer complains about it.
3. An MCCM could use an upstream transmitter to transmit signals in the upstream frequency band to check frequency response of the upstream. Some other piece of network test equipment could reside at the headend and monitor these signals and determine if there problems in the upstream portion of the network.
4. An MCCM could detect that given the measurement results at its location, that a neighbor on the network without an MCCM might have a problem that needs to be investigated. This problem could be addressed before the customer complains about it.

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Non-Publication Request: No

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