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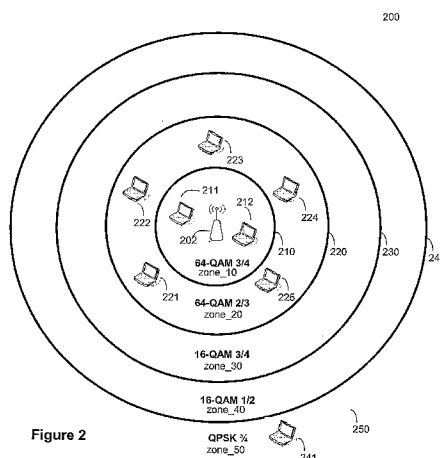
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(57) Abstract: A method is proposed to manage subscriber terminals within an multicast group in a manner that optimises bandwidth utilisation whilst maintaining the quality of service provided to each subscriber. In particular, where subscriber terminals experience different channel conditions, certain restrictions would normally be imposed on the modulation and coding scheme used to broadcast to the subscriber terminals. A metric is determined which indicates how much subscribers in an multicast group might have to downgrade the coding scheme by if a new subscriber terminal is admitted to the group or if any existing subscriber terminal experiences different channel conditions. This metric, referred to as a capability factor, is compared to a threshold to determine which subscribers to allow into the multicast group and which to deny. An associated modulation and coding scheme can also be determined for the resulting multicast group.

USER SELECTION IN WIRELESS NETWORKS

Field of the Invention

This invention relates to a method of managing subscriber terminals on a wireless multicast network, in particular a method of identifying subscriber terminals to admit to a wireless multicast group and to determine a modulation and coding scheme for each subscriber terminal.

Background to the Invention

When providing broadcast and multicast services in wireless access network, a base station transmits the same information or content to multiple subscribers at the same time. The term broadcast refers to the scenario where transmission is to all subscribers in the network connected to the base station, and multicast where transmission is to a subset of the subscribers connected to the base station. Thus, each subscriber within a particular group is able to receive the same broadcast or multicast information. For example, one group might provide music, and another group a particular TV channel. Such services could be supported by all popular wireless systems such as 2.5G, 3G, WiMAX, LTE, and so on. Though referred by different names in different technology families, the term Multicast and Broadcast Service (MBS) can be used in general. Examples of MBS include mobile TV, video streaming, periodic or regular service firmware updates, advertisement broadcast, etc.

MBS can be deployed as part of an existing cellular network (e.g. 3G UMTS or WiMAX), where a portion of the cellular network and radio resources is assigned to deliver MBS traffic in a centrally co-ordinated manner, and with an agreed quality-of-service (QoS) assurance. Different MBS content is delivered using different MBS channels. For example, TV content for the TV channel BBC1 might be broadcast in the MBS channel, MBS-channel-1, and TV content for BBC2 might be multicast in the MBS channel, MBS-channel-2. In order to view the content, the subscriber would need to be registered with the relevant MBS channel, which is usually referred to as an 'MBS group' as it represents a group of subscribers registered for some particular content. The wireless base station transmitting the content would evaluate

the radio channel conditions of the subscriber in order to decide whether the subscriber can be registered for the content and the level of QoS that should be used for the duration of the service. Furthermore, as there will be more than one subscriber registered to a MBS group, all subscribers in that group will be broadcast the same data.

After registration, the subscriber terminal listens to a dedicated control channel broadcast by the base station to obtain parameters associated with the various MBS channels. The terminal configures its receiver settings accordingly to tune into a particular time slot and/or frequency channel associated with the MBS group/channel of interest.

However, problems arise due to the inherent characteristics of wireless radio channels and the nature of subscriber mobility, where the signal quality received by a particular subscriber is affected by factors such as Doppler effect, fast fading, shadowing, scattering, reflection, and diffraction, which all cause the received signal strength to fluctuate across multi-dimensional domains (spatial, temporal, and frequency). Thus, in an MBS group, each subscriber will normally experience different channel qualities at any given broadcast frequency or time frame. It is therefore important for the base station to transmit to the MBS group at a link rate supported by the registered subscriber who has the worst signal quality in order to make sure all subscribers in the group are able to receive the transmitted content at minimum tolerable errors.

In situations when the signal-to-noise ratio or SNR (an indicator of the quality of the radio channel where a high SNR represents a good quality channel), is low, a lower order Modulation and Coding Scheme (MCS) is typically used. Lower order MCS encodes the data bits for transmission at a lower rate with more redundancy in order to increase robustness but at the expense of longer transmission time for the same content. This inherently increases the number of packets being queued at the buffer before being transmitted, therefore introducing extra delay. For real-time traffic that comes with tight transmission conditions, data packets that cannot be sent or received on time will be dropped. As a result, time-sensitive traffic will suffer increased packet drop rates, degrading the QoS and subscriber experience.

In wireless systems that allocate a dedicated size of resource for MBS services, such as WiMAX, this resource is referred as an MBS zone 106a and is located within a downlink (DL) frame 106 as shown in Figure 1 (for time division duplex configuration). The remainder of DL subframe 106b is usually allocated for unicast services such as voice, data download, web browsing, etc. However, the size of the frame is finite, so if more resources are allocated to MBS services, less resource is left for unicast services and vice versa.

Consider the following example, where a subscriber with low SNR, who can only support a lower order MCS, such as QPSK, will force all other subscribers in the same MBS group that may be capable of supporting a higher order MCS, such as 64-QAM, to use the lower order MCS. As a result, there will be a significant reduction, which in the case of QPSK compared with 64-QAM is approximately a 3 times reduction, in the transmission efficiency. Put another way, it would take 3 times longer to transmit the same amount of data using QPSK.

In another example, there may be a large number of subscribers who are connected to same base station in the same MBS group who would like to watch a live football match. If one of those subscribers, say subscriber A, is moving away from the base station there will be a drop in its received SNR. In order to make sure subscriber A continues to receive the multicast content according to a service level agreement, the base station will have to transmit using a lower order MCS required by the subscriber A. However, as subscriber A is a member of an MBS group, in order to transmit to subscriber A with a lower order MCS, all subscribers in that group will need to be transmitted to at the same MCS, even though the majority are able to receive a higher order MCS. Furthermore, if the base station intends to maintain the QoS of all subscribers in such situation where a lower order MCS is used, the base station has to allocate more radio resources such as bandwidth, power, or time/frequency slots. For the earlier example of QPSK and 64-QAM, 3 times the resources will be needed. However, this is a problem as the base station will only have a limited amount of resource allocated for supporting MBS services and these resources will need to be shared amongst all the MBS groups supported. Failing to do so will result in data packets arriving with larger delays and jitters, which can result in static screens for video, or frames might be corrupted that receiver is unable to recover, which can result in corrupted screens for video when packets are

dropped due to excessive delays or transmission loss. In many situations, such as when viewing a live football match, this will be unacceptable to the subscriber.

Summary of the Invention

It is the aim of embodiments of the present invention to address one or more of the above-stated problems, and to provide an improved method managing subscriber terminals on a wireless multicast network, in particular a method of identifying subscriber terminals to admit to a wireless multicast group and to determine a modulation and coding scheme for each subscriber terminal.

According to a first aspect of the present invention, there is provided a method of managing a plurality of subscriber terminals in a wireless network, wherein each subscriber terminal can support a corresponding maximum transmission coding scheme for wireless transmissions between a base station and said each subscriber terminal, and wherein the plurality of subscriber terminals are split into a first and second set of subscriber terminals where each of the subscriber terminals in the first set supports a higher order maximum transmission coding scheme than the subscriber terminals in the second set, said method comprising:

- a) calculating a metric equal to the ratio of a first parameter to a second parameter, wherein
 - i) the first parameter represents the total number of bits received within a fixed interval by a first subset of the plurality of subscriber terminals when each of the subscriber terminals in the first subset uses the lowest order transmission coding scheme of all the corresponding maximum transmission coding schemes supported by each of the subscriber terminals in the first subset, and
 - ii) the second parameter represents the total number of bits received within a fixed interval by each of the plurality of subscriber terminals when each of the plurality of subscriber terminals uses their corresponding optimum transmission coding scheme;
- b) comparing the calculated metric to a predetermined threshold, and if the calculated metric is above the threshold, then scheduling multicast transmissions by the base station to the first subset of the plurality of subscriber terminals using the lowest order transmission coding scheme of all the corresponding maximum

transmission coding schemes supported by each of the subscriber terminals in the first subset.

The calculated metric is referred to in preferred examples as the capability factor

Preferably, the calculated metric is above the predetermined threshold, the multicast transmissions by the base station form part of a first multicast and broadcast services group.

If the calculated metric is above the predetermined threshold, the method may further comprise scheduling multicast transmissions by the base station to the second subset of the plurality of subscriber terminals using the lowest order transmission coding scheme of all the corresponding maximum transmission coding schemes supported by each of the subscriber terminals in the second subset.

If the calculated metric is above the predetermined threshold, the method may further comprise scheduling unicast transmissions by the base station to each of second subset of the plurality of subscriber terminals.

Preferably, the transmission coding scheme is a modulation and coding scheme for wireless data transmission.

The maximum transmission coding scheme may be the highest order modulation and coding scheme that can be supported by corresponding subscriber terminal over the transmission channel to the base station.

Preferably, the maximum transmission coding scheme is dependent on the signal to noise ratio of the wireless transmission channel between the base station and the corresponding subscriber terminal.

Preferably, the fixed interval is at least one of a time slot, a frequency band, or a combination of both.

According to a second aspect of the invention, there is provided a controller unit for managing a plurality of subscriber terminals in a wireless network, wherein each

subscriber terminal can support a corresponding maximum transmission coding scheme for wireless transmissions between a base station and said each subscriber terminal, and wherein the plurality of subscriber terminals are split into a first and second set of subscriber terminals where each of the subscriber terminals in the first set supports a higher order maximum transmission coding scheme than the subscriber terminals in the second set, said controller comprising:

- a) a processing module adapted to calculate a metric equal to the ratio of a first parameter to a second parameter, wherein
 - i) the first parameter represents the total number of bits received within a fixed interval by a first subset of the plurality of subscriber terminals when each of the subscriber terminals in the first subset uses the lowest order transmission coding scheme of all the corresponding maximum transmission coding schemes supported by each of the subscriber terminals in the first subset, and
 - ii) the second parameter represents the total number of bits received within a fixed interval by each of the plurality of subscriber terminals when each of the plurality of subscriber terminals uses their corresponding optimum transmission coding scheme; and
- b) a comparison module adapted to compare the calculated metric to a predetermined threshold, and if the calculated metric is above the threshold, then scheduling multicast transmissions by the base station to the first subset of the plurality of subscriber terminals using the lowest order transmission coding scheme of all the corresponding maximum transmission coding schemes supported by each of the subscriber terminals in the first subset.

Examples of the invention provide QoS to subscribers by selecting the MCS that best suit the majority of subscribers. Furthermore, bandwidth efficiency is provided by isolating weak signal strength subscribers and provides them an alternative servicing solution (not just unicast). This ensures maximum bandwidth efficiency and at the same time ensures a good service experience to the subscriber.

A base station implementing an example of the invention will be able to intelligently manage the subscribers within an MBS group with aim of conserving bandwidth resources in the MBS zone, and at the same time also try to satisfy the QoS of the majority of the subscribers.

The invention maximises the multicast transmission opportunity in bandwidth limited conditions. In the example of WiMAX, the allocation for multicast is very small compared to that for unicast transmissions, so it is advantageous to maximise the spectrum efficiency and maximise the number of simultaneous multicast channels that can be used. Subscribers that do not make the “cut” can be re-assigned into the unicast queue, where the WiMAX scheduler can treat it as normal traffic and provide the necessary scheduling, taking the QoS requirements into consideration.

Brief Description of the Drawings

For a better understanding of the present invention reference will now be made by way of example only to the accompanying drawings, in which:

Figure 1 is an example of a typical transmission frame structure in a time-division duplex system, where the frame is divided in time into downlink and uplink subframes;

Figure 2 is a system showing typical variations in MCS supported terminals depending on the distance the base station;

Figure 3 is a table showing how the MCS that can be supported varies with the signal to noise ratio in the transmission channel;

Figure 4 is flow chart illustrating the steps of calculating the capability factor and subsequent handling of subscriber terminals;

Figure 5 is a table illustrating various MCSs and the corresponding number of data bits that can be carried using that MCS;

Figure 6 is a table showing the calculated capability factor for various terminals in an example of the present invention;

Figure 7 is a table showing how the setting of various thresholds for the capability factor can influence the MCS selection;

Figure 8 shows how the flexibility of a system in an example of the invention is affected by the threshold set; and

Figure 9 is a block diagram illustrating a controller unit for a base station in an example of the present invention.

Description of Preferred Embodiments

The present invention is described herein with reference to particular examples. The invention is not, however, limited to such examples.

In examples of the present invention there is proposed a method to manage subscriber terminals within an multicast group in a manner that optimises bandwidth utilisation whilst maintaining the quality of service provided to each subscriber. In particular, where subscriber terminals experience different channel conditions, certain restrictions would normally be imposed on the modulation and coding scheme used to broadcast to the subscriber terminals. A metric is determined which indicates how much subscribers in an multicast group might have to downgrade the coding scheme by if a new subscriber terminal is admitted to the group or if any existing subscriber terminal experiences different channel conditions. This metric, referred to as a capability factor, is compared to a threshold to determine which subscribers to allow into the multicast group and which to deny. An associated modulation and coding scheme can also be determined for the resulting multicast group.

Figure 2 shows a wireless network arrangement 200, comprising a base station 202, and a series of m (in the specific example, $m=6$) wireless subscriber terminals 211, 212, 221, 222, 223, 224, 225 and 241. The wireless network in this example is a WiMAX (IEEE 802.16) network, though a person skilled in the art will appreciate that the methods described below can be applied to other wireless networks such as WiFi and 3G UMTS. The base station 202, which may be a wireless router or similar transceiver, can connect wirelessly to any other of the wireless terminals within its radio transmission range. The wireless terminals can be laptops, smartphones, PDAs or other similar devices configured with a suitable WiMAX interface.

In the example network 200, all the subscriber terminals start off in the same multicast and broadcast service (MBS) group, that is to say, they are all registered to receive broadcasts relating to the same MBS channel/content.

Typically, registration starts with a subscriber terminal scanning for a network upon power up of the terminal. Once the base station 202 has been detected and selected for connection, the subscriber terminal communicates with the base station 202 and performs various connection processes, which includes amongst other

things, key exchange, password verification, subscription authentication, fetching of SLA parameters, downloading of user profiles and triggering of initial services. The terminal is then accepted into the network.

The subscriber terminals also perform 'ranging' and 'synchronisation', where they return their measured received signal strength and signal to noise ratio (SNR) to the base station 202. From this parameter, the base station 202 can determine the channel condition between the subscriber terminal and the base station 202.

Armed with these measurements, the base station 202 can determine a suitable MCS that can best serve that a particular subscriber terminal. For adaptive channel coding, the subscriber terminal sends the measured strength back to the base station from time to time. Similarly, the base station can also measure the uplink signal strength from the subscriber terminal when the subscriber terminal transmits data back to the packets to base station 202. Thus, the base station always has knowledge of the condition of the connected subscriber terminals.

The network 200 is divided into several zones: zone_10 210, zone_20 220, zone_30 230, zone_40 240, and zone_50 250. Subscribers in each zone experience different radio channel conditions and thus support different maximum modulation codec schemes (MCS). In this example, subscriber terminals 211 and 212 located in zone_10 210 have favourable channel conditions and are thus able to support a high order MCS, 64-QAM $\frac{3}{4}$. Similarly, subscriber terminals 221, 222, 223, 224 and 225 also have relatively good channel conditions and are able to support a relatively high order MCS, 64-QAM $\frac{2}{3}$. However, the subscriber terminal in zone_50 250 experiences poor channel conditions and can only support a lower order MCS of QPSK $\frac{3}{4}$.

The channel conditions affecting any given subscriber terminal can result from many factors such as Doppler effect, fast fading, scattering and reflection of the radio signals transmitted over the channel to and from the subscriber terminal. One measure of the channel condition is the signal to noise ratio (SNR) associated with a channel or the signal strength of transmissions in that as measured by the subscriber terminal or the base station 202 as described above.

Based on the determined channel conditions, the base station 202 selects a suitable MCS. Figure 3 shows a table 300 which illustrates the relationship between various MCS schemes 302 and SNR 304 in typical wireless systems. Thus, an MCS of QPSK $\frac{1}{2}$ requires only a relatively low SNR (a poor channel quality) to operate and can thus be considered to be quite robust, but in turn can only carry a limited number of data bits per slot in the channel, as a lot of additional data is required to provide the redundancy that results in the robustness. Conversely, an MCS of 64-QAM $\frac{2}{3}$ requires a relatively high SNR (a good channel quality), so is far less robust, but is able to carry more data bits per slot.

In network 200, zone_10 210 terminals can support an MCS of 64-QAM $\frac{3}{4}$, zone_20 220 terminals can support an MCS of 64-QAM $\frac{2}{3}$, zone_30 230 can support an MCS of 16-QAM $\frac{3}{4}$, zone_40 240 can support an MCS of 16-QAM $\frac{1}{2}$, and zone_50 250 can support an MCS of QPSK $\frac{3}{4}$. Whilst the zones are shown to radiate concentrically from the central base station 202 and the associated MCS to drop with increasing distance (so subscriber terminal 241 having the lowest SNR and thus requiring a low order MCS), this is a simplification made for purposes of clarity. In practice, subscriber terminals close to the base station may experience poor channel conditions and thus require a low order MCS – so for example, subscriber terminal 225 in zone_20 may suffer some local interference and degradation in channel quality (and hence have a low SNR), and thus require a low order MCS such as QPSK $\frac{3}{4}$. Nonetheless, the methods described are applicable to any SNR pattern as they examine the channel characteristics experienced by individual subscriber terminals and not those of a given zone.

The base station 202 relays information regarding the MCS selected in the header of the frames being transmitted - information identifying the MCS selected is inserted into the header at the beginning of every frame of data that is encoded using the selected MCS. The header itself is encoded and broadcast using a very robust predetermined transmission mechanism so that the receiving subscriber terminals can decode it reliably. So, the receiving subscriber terminal MS will receive and decode the header information, and thus be able to determine the MCS assigned to it, as well as at which time slot and frequency channel to transmit and receive. In an MBS scenario, several subscriber terminals will be told to listen at the same time/frequency. The subscriber terminals receive various important commands from

the header portion of the transmitted packets. In WiMAX, the frame structure and properties are defined in the DL_MAP and UL_MAP of the header, relating to the downlink and uplink channel properties respectively.

Assuming that subscriber terminal 241 experiences the worst channel quality (the lowest SNR) of all the subscriber terminals, and requires an MCS of QPSK $\frac{3}{4}$, then the base station 202 will be forced to broadcast using QPSK $\frac{3}{4}$ to subscriber terminal 241 if that terminal is to receive the data without a loss of QoS. However, if subscriber terminal 241 is part of an MBS group that includes all the other subscriber terminals shown in Figure 2, then all the other subscriber terminals will be forced to receive the same data broadcast at the lower order MCS of QPSK $\frac{3}{4}$. Thus, the presence of subscriber terminal 241 experiencing poor channel conditions forces all other terminals in the same MBS group to adopt a lower order MCS. And as described earlier, this can cause problems when there is limited bandwidth for transmissions. The base station 202 can change the MCS used and notify the terminals using the header portion as described above.

This problem of is solved in a preferred example of the invention, where a method is used to quantify the overall impact on the bandwidth utilisation efficiency when subscribers with different SNR qualities are admitted into a MBS group. The method determines a metric referred to as a capability factor. The general method is described below with reference to the method flow diagram of Figure 4.

In Figure 4, in step 400, the base station BS 202 gathers channel state information for all the m terminals in the network, and determines the signal to noise ratio (SNR) associated with each of the m terminals. The assumption is that all m terminals are subscribing to the same MBS group. The same procedure can be applied separately to any other MBS groups present in the system.

In step 402, the base station 202 sorts the m terminals in order of descending SNR, so that the terminal with the highest SNR ratio is ranked first. The MCS supported by each terminal is also determined. Using the network 200 as an example, terminal 211 experiences a relatively high SNR ratio and thus be ranked quite high, whereas terminal 241 experiences a relatively low SNR and thus be ranked quite low. As a consequence of the high SNR, terminal 211 would be able to support a high order

MCS such as 64-QAM $\frac{3}{4}$ as illustrated, whereas terminal 241 experiencing a low SNR would only be able to support QPSK $\frac{3}{4}$.

In step 404, the base station 202 starts calculating for each terminal starting with the first ranked terminal ($n = 1$) a metric referred to as a capability factor ζ_n . A capability factor is calculated iteratively (steps 406 to 412) for each of the m terminals until a certain condition is met: the calculated capability factor for a given terminal is less than a predetermined threshold χ (see step 408).

The capability factor gives a measure of how much existing terminals will be affected by the introduction of a subsequent terminal (the terminal for which the capability factor is being calculated).

First, a variable ψ_n is calculated according to equation (1) and refers to the total number of bits that the first n terminals can receive using their respective individual best MCS (subject to individual channel condition) in a fixed time slot.

$$\psi_n = \sum_{k=1}^n \lambda_k \quad (1)$$

where λ_k is the number of bits that terminal k (where $k = [1, n]$) can receive using its best MCS that can be supported (subject to channel condition) in a fixed time slot.

Thus, ψ_n represents the total number of bits received within a fixed timeslot by all n terminals, where each terminal uses their individual highest order MCS that can be supported, regardless of whether or not the highest order MCS of that particular terminal can also be supported by other terminals.

Then, a variable ψ_l is calculated according to equation (2) and refers to the total number of bits that the n terminals can receive using the lowest common MCS for all terminals in a fixed time slot i.e. the 'common' best MCS that all n terminals can support subject to channel conditions.

$$\psi_l = n \times \lambda_l \quad (2)$$

where, λ_l is the number of bits that terminal n (the n^{th} terminal) can receive with its best MCS, which will as a result of the sorting procedure earlier be the lowest common MCS of all n terminals in a fixed time slot.

Thus, ψ_l represents the total number of bits received within a fixed timeslot by all n terminals when the n^{th} terminal is included into the group using the lowest common MCS. It is computed using the best MCS that all n terminals can support, which is essentially the MCS of the n^{th} terminal since all previously terminals can support this MCS or higher due to the sorting procedure in step 402.

The capability factor ζ_n is calculated in step 406 according to equation (3) as follows:

$$\zeta_n = \frac{\psi_l}{\psi_n} \quad (3)$$

Then in step 408, a check is performed by the base station 202 to see if the calculated capability factor ζ_n as a result of the n^{th} terminal is below a predetermined threshold, χ . The relevance of the threshold χ will be explained later with reference to an illustrative example.

If the capability factor is not less the threshold χ , then the subscriber terminal n is placed in Queue_A, and the preferred MCS of that subscriber terminal (the best MCS that it can support) is recorded. This MCS will naturally be able to be supported by all the terminals in queue A as all previously processed terminals by virtue of the ranking in step 402 will be able to support that MCS or a higher MCS. Processing then turns to step 412 where a check is made to see if all the ranked subscriber terminals have been processed. If they have not been, then processing turns back to step 406, whilst incrementing n by 1 so that the next subscriber terminal in the ranked list is examined and processed. If all subscriber terminals have been processed, then processing continues to step 416.

If in step 408, the capability factor ζ_n for subscriber terminal n is less than the threshold χ , then processing passes to step 414. In step 414, subscriber terminal n is placed in Queue_B together with the remaining terminals in the ranked queue that have yet to be processed (i.e. up to m). In effect, this places subscriber terminals having relatively low SNR into Queue_B in accordance with the measured parameter of the capability factor ζ_n .

In step 416, the base station 202 schedules MBS broadcasts to all the subscriber terminals in Queue_A using the last recorded 'best MCS' which will be supported by all subscriber terminals within the queue.

In step 418, the base station 202 services the subscriber terminals in Queue_B in various ways depending on resource availability:

1. Provide unicast services to the terminals in Queue_B on a best effort basis. The base station can maintain the original QoS requirement of the subscriber terminals by allocating more resources (e.g. timeslots) in unicast mode if the unicast resource has sufficient capacity.
2. Allocate unused MBS zone resources to subscriber terminals in Queue_B. This is only allowed if the subscriber terminals in Queue_A have already been handled and there is sufficient resource remaining in the MBS zone to assign to Queue_B. Furthermore, as the main objective is to conserve MBS zone bandwidth resource, the resources given to Queue_B should be given over to Queue_A if it is ever required. This will conserve bandwidth resources in the MBS Zone.

Using the method above, the content of a particular MBS channel can be delivered using an optimally selected MCS, which leaves more resources (time slots) for transmission of other MBS channels.

Turning back to the system 200 illustrated in Figure 2, first all subscriber terminals in zone_10 210 will go through the evaluation steps above, as they have the highest SNR followed by subscriber terminals in zone_20 220 and lastly subscriber terminal 241 in zone_50 250. When the first subscriber in zone_20 enters the evaluation

process after all subscribers in zone_10 have been evaluated, the calculated capability factor will decrease from 1 to 0.914 because of a lower order MCS required for each of the subscribers in zone_20. If the threshold χ is set at 0.8, the capability factor would still be above the threshold value (step 408), and so the subscriber terminals in zone_20 will be accepted into the group and placed into Queue_A (step 410). On the other hand, when subscriber terminal in zone_50 is examined, the capability factor will reduce to 0.383 which is below the threshold χ . Therefore, subscriber terminal 241 in zone_50 will be allocated into Queue_B (step 414). After all the subscriber terminals have been examined, the base station 202 can broadcast the content to all subscriber terminals in Queue_A using an MCS of 64-QAM 2/3 modulation (the last recorded preferred MCS from a subscriber terminal in zone_20) and possibly unicast the same content to the subscriber terminal 241 in zone_50 that was placed in Queue B using an MCS of QPSK $\frac{3}{4}$ modulation.

Figure 5 shows a table 500 illustrating various modulation schemes 502 and the corresponding number of data bits 504 that can be carried in one 5Mhz symbol in an OFDMA (WiMAX) system. It has been assumed that one symbol is equal to one fixed time slot. The precise figures for bits per 5MHz symbol are not important, and the intention is just to illustrate that different MCSs have different data capacities. The column 506 headed "normalised capacity" gives a unit measure of the number of bits a given MCS can carry relative to the lowest MCS, which in this case is QPSK $\frac{1}{2}$.

If we assume an illustrative payload size of 5000bits, instead of using 9 timeslots to broadcast the content with QPSK $\frac{3}{4}$ (9 slots x 576bits = 5184 bits), the base station can use only 4 timeslots to broadcast the content to all the strong subscriber terminals in Queue_A using 64-QAM 2/3 modulation (4 slots x 1536 = 6144 bits).

The process can be repeated to check other MBS groups supported by the base station 202 in the network. By reducing the number of timeslots used in the MBS zone for a given MBS group, the remaining timeslots can be allocated to other MBS groups and possibly more MBS groups.

There now follow a series of examples of the calculated capability factor, together with a discussion on the relevance of the threshold χ .

The table 600 in Figure 6 shows the capability factor ς calculated according to the method described above for 10 subscriber terminals, experiencing different channel conditions and hence able to support different MCSs. As can be seen from the MCSs in column 602, the terminals have been sorted in order of ascending MCS, or descending SNR. Column 602 lists various MCSs and also the number of subscriber terminals that can support such an MCS. Column 604 shows a normalised capacity. Column 606 shows the relative number of time slots required to send the same amount of data for each of the MCSs. Column 608 shows the capability factor ς as calculated when the subscriber with the corresponding MCS is admitted to the group using the method described above. For simplicity, the capability factor calculated here has been done on per-MCS group basis with all terminal that support the same maximum MCS having the same capability factor. If the exact method described above is used where each terminal is examined iteratively, then the capability factor would be slightly different – for example, the 3 terminals supporting 16-QAM $\frac{3}{4}$ would not all have a capability factor of 0.88, but capability factors of 0.81, 0.86 and 0.88. However, a general capability factor for all three of these terminals in this MCS group of 0.88 has been retained for simplicity.

When admitting a given subscriber terminal n , if the calculated capability factor, ς , is found to be larger than the threshold value, χ , (see step 408) subscriber terminal n (effectively classified as having a high SNR) will be admitted into Queue_A (step 410). If the calculated capability factor, ς , is lower than the threshold value (step 414), it is placed in Queue_B (effectively representing a low SNR).

Table 700 in Figure 7 shows how the selected MCS varies depending on the selected threshold χ . The 4 columns 702, 704, 706 and 708 illustrate 4 differing cases each with a different threshold χ .

In the example where the threshold χ is set to 0.9, the 2 subscriber terminals supporting 64-QAM $\frac{2}{3}$ are processed first (the terminals having already been sorted in descending SNR) and each result in a calculated capability factor $\varsigma = 1$. This is greater than the threshold χ of 0.9 and both are placed in Queue_A and a preferred MCS of 64-QAM $\frac{2}{3}$ is recorded. However, when processing turns to the next terminal supporting an MCS of 16-QAM $\frac{3}{4}$, the calculated capability factor is 0.88

(see column 608 in Figure 6), and thus the terminal and all remaining terminals are placed in Queue_B. Thus, the 2 subscriber terminals in Queue_A (which can be seen as a strong subscriber group) are served by a high order MCS of 64-QAM $2/3$, while the remaining 8 subscriber terminals in Queue_B are forced to share the same MCS, QPSK $1/2$, even though only 1 subscriber terminal is actually using this MCS. This implies that when the threshold $\chi = 0.9$, the system does not have the flexibility to adapt to use even only a 1 level lower MCS to provide a better rate to terminals that can support 16-QAM $3/4$.

On the other hand, when the threshold $\chi = 0.8$, each of the first 5 terminals in the ordered list 602 result in a computed capability factor above the threshold (with capability factors of 1, 1, 0.88, 0.88 and 0.88 - see 608), and thus these first 5 terminals are placed in Queue_A and a preferred MCS of 16-QAM $3/4$ is recorded. The remaining terminals have capability factors of below the threshold (see 608) and are thus all placed into Queue_B and given an MCS of QPSK $1/2$. Effectively, the system has the flexibility to adapt to an MCS a few levels lower than the highest MCS by using 16-QAM $3/4$, and thus provide service to a larger number of subscriber terminals, specifically 5 compared to 2 when the threshold was 0.9. This flexibility is important in a wireless system due to the fact that wireless channel conditions fluctuate over time and a certain level of flexibility helps to avoid unnecessary changes in the Quality of Service (QoS) provided to the subscriber terminals as a result of frequent changes in the MCS.

Looking at yet another example where the threshold $\chi = 0.5$, each of the first 9 subscriber terminals are admitted into Queue_A with MCS of QPSK $3/4$ (all 9 have a capability factor above the threshold). The 10 terminal is placed in Queue_B as it results in a capability factor of 0.417, below the threshold. Thus, setting the threshold to 0.5 offers greater flexibility but gains little in optimising bandwidth efficiency since there are 9 terminals in Queue A are still served using a low rate – QPSK $3/4$.

And finally, when the threshold $\chi = 0.2$, all subscribers in the group will be included into the multicasting group as the lowest capability factor is calculated to be 0.417, which is above the threshold. In this example, all subscriber terminals are placed in Queue_A and are forced to use QPSK $1/2$ even though many of the terminals are

capable of receiving at a much higher rate MCS. If the terminals suffering bad channel conditions can be isolated and removed from Queue_A, then the 'good' terminals in Queue-A can be served using a higher rate MCS and hence optimise bandwidth utilisation efficiency in the MBS zone. One way to do this is by changing the threshold, for example to 0.5.

The actual setting of the threshold can change dynamically depending a variety of conditions, such as the traffic loads condition in both the multicast and unicast, the number of slots available for the MBS zone, the number of simultaneous MBS channels, and the required QoS.

Figure 8 shows how the threshold χ that is set can affect the flexibility of the system, that is to say, the ability of the system to adapt to changes and manage the MCS used by the terminals without frequent modification. When the threshold is set to a small value, the system is a lot more flexible (although resource usage will be high) as more terminals will be able to join the MS group and adopt the relatively low order MCS. In contrast, when the threshold is set high, the system as a whole is less flexible - many terminals rejected (but fewer resources are used) and the MCS adopted will be relatively high.

As we can see from the table in Figure 7, a threshold χ of 0.8 provides a balanced solution between flexibility and capacity utilization. Other threshold values might be more appropriate depending on the specific requirements of the system as a whole.

Therefore, the method proposed of calculating the parameter of the capability factor by a base station measures and reacts (by comparison to a threshold) to conditions in the system. This provides an efficient yet balanced solution to support subscriber terminals in MBS group where the terminals experience different channel conditions. With careful selection of the threshold value for the capability factor, χ , the resource utilization of subscriber terminals can be optimized by selecting the best combination of MCS for the high SNR and low SNR terminals in the multicast group.

Figure 9 shows a base station controller unit 900 for implementing examples of the present invention. The controller unit comprises an input 901, for receiving data relating to channel conditions from the various subscriber terminals. The channel

data might include the signal strength or signal to noise ratio associated with the radio channel to the corresponding subscriber terminal. The channel data is passed to the channel condition estimator 902, which estimates the channel conditions associated with each of the subscriber terminals as set out in step 400. The sorting module 904 is used to sort the terminals in order of descending SNR according to step 402 in a preferred example of the invention. The processing module 906 is used to perform steps 404 and 406 of calculating the capability factor for each of the subscriber terminals. The comparison module 908 makes the comparison between the calculated capability factor and the threshold as well as placing the terminals in the requisite queue as set out in step 408, 410 and 414. The queues can be stored in the data store 812. The channel allocator 910 then schedules broadcasting of data with the suitable MCS as set out in steps 416 and 418. The group and channel requirements are then provided to the subscriber terminals over output 911.

A person skilled in the art will appreciate that each of the modules described above that make up the controller unit 900 can be implemented as a software module, hardware module, or a combination of the two. Furthermore, the controller unit 900 may be away from the base station as a separate unit, but with suitable connections to transfer the required data to the base station.

Examples of the invention based upon software can be realised, at least in part, by executable computer program code which may be embodied in application program data stored in the controller unit 900 in the data store 912. When such computer program code is loaded into the memory of the associated device for execution, it provides, in conjunction with an executing processing unit in that device, a computer program code structure which is capable of performing at least part of a method in accordance with the herein above described exemplary examples of this invention.

Furthermore, a person skilled in the art will appreciate that the computer program structure referred can correspond to the process flow chart described above, where each step of the flow chart can correspond to at least one line of computer program code and that such, in combination with a processing unit in the corresponding controller unit 800, provides apparatus for effecting the described process.

In general, it is noted herein that while the above describes examples of the invention, there are several variations and modifications which may be made to the described examples without departing from the scope of the present invention as defined in the appended claims. One skilled in the art will recognise modifications to the described examples.

CLAIMS

1. A method of managing a plurality of subscriber terminals in a wireless network, wherein each subscriber terminal can support a corresponding maximum transmission coding scheme for wireless transmissions between a base station and said each subscriber terminal, and wherein the plurality of subscriber terminals are split into a first and second set of subscriber terminals where each of the subscriber terminals in the first set supports a higher order maximum transmission coding scheme than the subscriber terminals in the second set, said method comprising:
 - a) calculating a metric equal to the ratio of a first parameter to a second parameter, wherein
 - i) the first parameter represents the total number of bits received within a fixed interval by a first subset of the plurality of subscriber terminals when each of the subscriber terminals in the first subset uses the lowest order transmission coding scheme of all the corresponding maximum transmission coding schemes supported by each of the subscriber terminals in the first subset, and
 - ii) the second parameter represents the total number of bits received within a fixed interval by each of the plurality of subscriber terminals when each of the plurality of subscriber terminals uses their corresponding optimum transmission coding scheme;
 - b) comparing the calculated metric to a predetermined threshold, and if the calculated metric is above the threshold, then scheduling multicast transmissions by the base station to the first subset of the plurality of subscriber terminals using the lowest order transmission coding scheme of all the corresponding maximum transmission coding schemes supported by each of the subscriber terminals in the first subset.
2. A method as claimed in claim 1 wherein if the calculated metric is above the predetermined threshold, the multicast transmissions by the base station form part of a first multicast and broadcast services group.
3. A method as claimed in claim 1 or claim 2, wherein if the calculated metric is above the predetermined threshold, the method further comprises scheduling multicast transmissions by the base station to the second subset of the plurality of

subscriber terminals using the lowest order transmission coding scheme of all the corresponding maximum transmission coding schemes supported by each of the subscriber terminals in the second subset.

4. A method as claimed in claim 1 or claim 2, wherein if the calculated metric is above the predetermined threshold, the method further comprises scheduling unicast transmissions by the base station to each of second subset of the plurality of subscriber terminals.

5. A method according to any of the preceding claims wherein the transmission coding scheme is a modulation and coding scheme for wireless data transmission.

6. A method according to any preceding claim wherein the maximum transmission coding scheme is the highest order modulation and coding scheme that can be supported by corresponding subscriber terminal over the transmission channel to the base station.

7. A method according to any preceding claim wherein the maximum transmission coding scheme is dependent on the signal to noise ratio of the wireless transmission channel between the base station and the corresponding subscriber terminal.

8. A method according to any preceding claim, wherein the fixed interval is at least one of the following: a time slot, a frequency band, or an orthogonal code.

9. A controller unit for managing a plurality of subscriber terminals in a wireless network, wherein each subscriber terminal can support a corresponding maximum transmission coding scheme for wireless transmissions between a base station and said each subscriber terminal, and wherein the plurality of subscriber terminals are split into a first and second set of subscriber terminals where each of the subscriber terminals in the first set supports a higher order maximum transmission coding scheme than the subscriber terminals in the second set, said controller comprising:

a) a processing module adapted to calculate a metric equal to the ratio of a first parameter to a second parameter, wherein

- i) the first parameter represents the total number of bits received within a fixed interval by a first subset of the plurality of subscriber terminals when each of the subscriber terminals in the first subset uses the lowest order transmission coding scheme of all the corresponding maximum transmission coding schemes supported by each of the subscriber terminals in the first subset, and
 - ii) the second parameter represents the total number of bits received within a fixed interval by each of the plurality of subscriber terminals when each of the plurality of subscriber terminals uses their corresponding optimum transmission coding scheme; and
- b) a comparison module adapted to compare the calculated metric to a predetermined threshold, and if the calculated metric is above the threshold, then scheduling multicast transmissions by the base station to the first subset of the plurality of subscriber terminals using the lowest order transmission coding scheme of all the corresponding maximum transmission coding schemes supported by each of the subscriber terminals in the first subset.

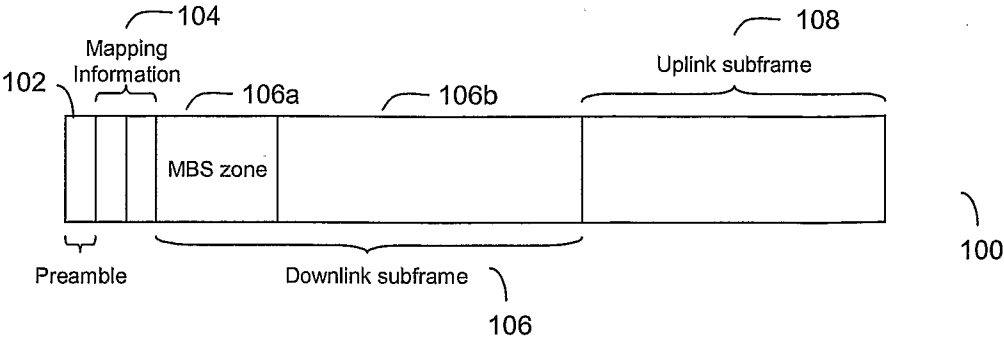


Figure 1

MCS	Required SNR (relative)
QPSK $\frac{1}{2}$	Low High
QPSK $\frac{3}{4}$	
16-QAM $\frac{1}{2}$	
16-QAM $\frac{3}{4}$	
64-QAM $\frac{1}{2}$	
64-QAM $\frac{2}{3}$	
64-QAM $\frac{3}{4}$	
64-QAM $\frac{5}{6}$	

Figure 3

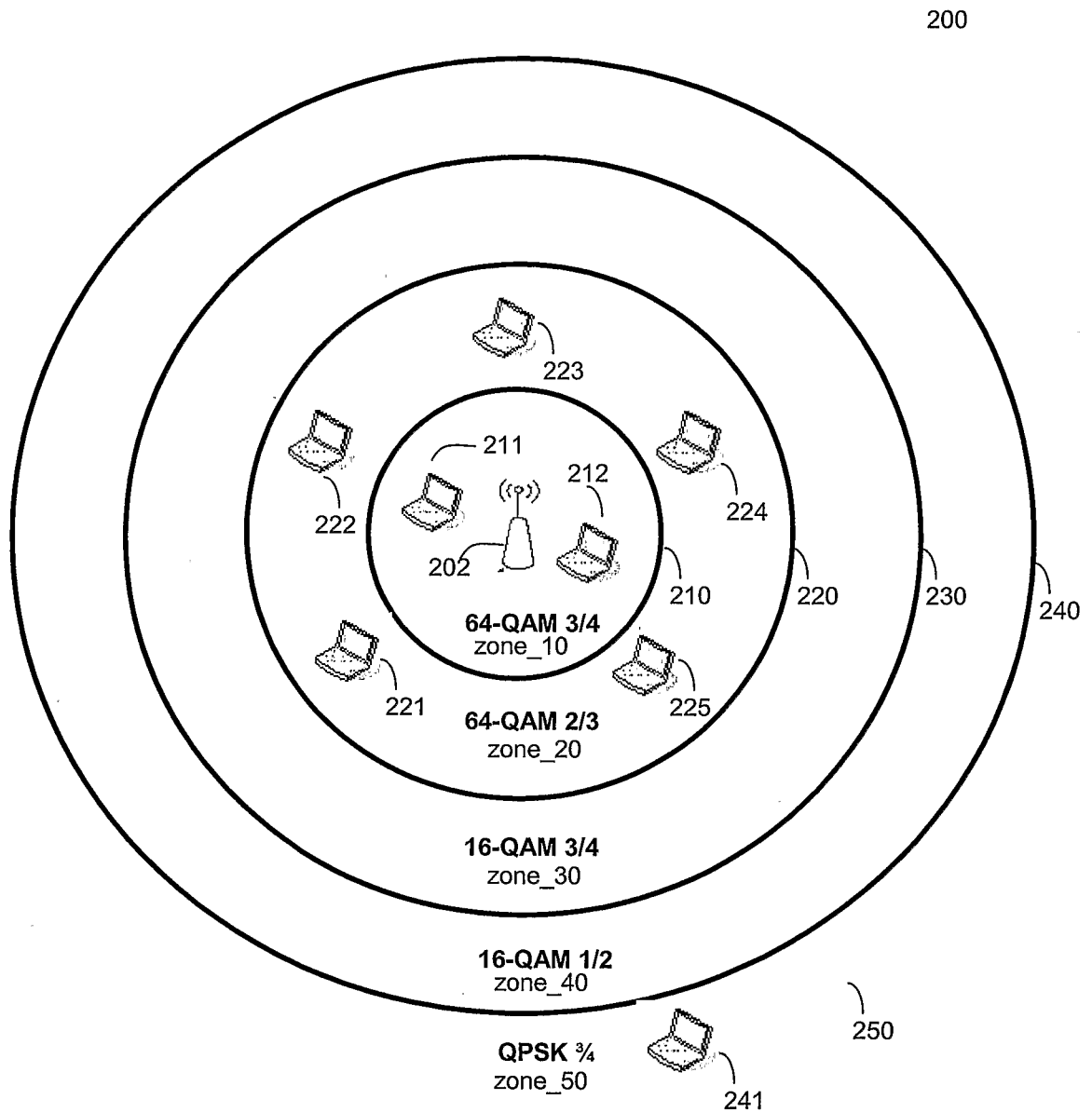


Figure 2

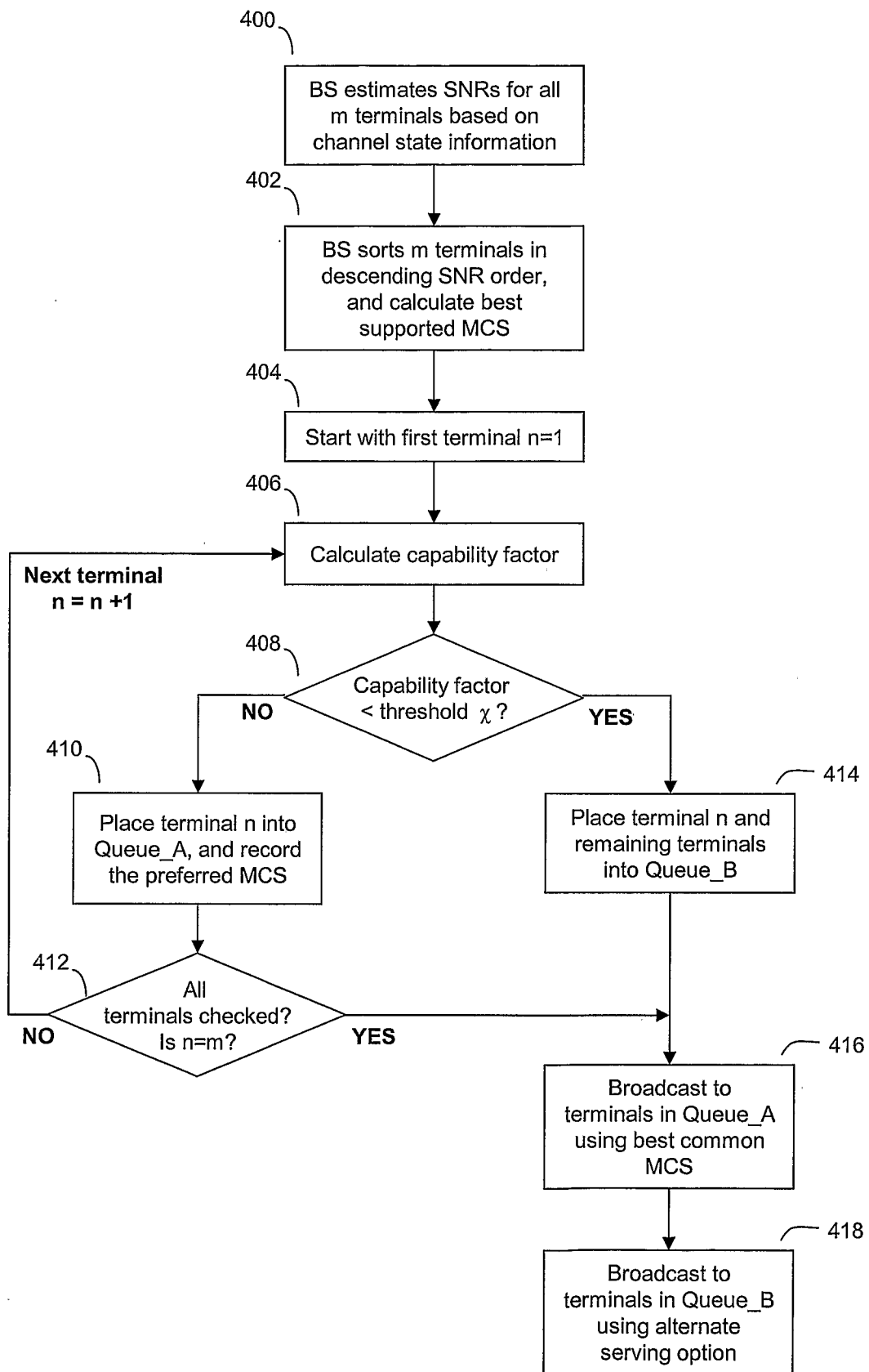


Figure 4

502 Modulation Schemes	504 MCS capacity measured by useful data bits per 5MHz symbol	506 Normalized capacity
QPSK 1/2	384 bits	1
QPSK 3/4	576 bits	1.5
16-QAM 1/2	768 bits	2
16-QAM 3/4	1152 bits	3
64-QAM 1/2	1152 bits	3
64-QAM 2/3	1536 bits	4
64-QAM 3/4	1728 bits	4.5
64-QAM 5/6	1920 bits	5

500

Figure 5

602 No. of terminals per MCS	604 Normalized capacity	606 Relative no. of time slots required to send the same amount data	608 Capability Factor value when subscriber terminal included into multicast group
2 x 64-QAM 2/3	4	1	$\frac{4 \times 2}{4 \times 2} = 1$
3 x 16-QAM 3/4	3	1.5	$\frac{3 \times 5}{4 \times 2 + 3 \times 3} = 0.88$
4 x QPSK 3/4	1.5	3	$\frac{1.5 \times 9}{4 \times 2 + 3 \times 3 + 1.5 \times 4} = 0.587$
1 x QPSK 1/2	1	4	$\frac{1 \times 10}{4 \times 2 + 3 \times 3 + 1.5 \times 4 + 1 \times 1} = 0.417$

600

Figure 6

	702	704	706	708
Chosen Predetermined Threshold value	$\chi = 0.9$	$\chi = 0.8$	$\chi = 0.5$	$\chi = 0.2$
Number of subscriber terminals in Queue_A and selected MCS	2 terminals with 64-QAM $\frac{2}{3}$	5 terminals with 16-QAM $\frac{3}{4}$	9 terminals with QPSK $\frac{3}{4}$	10 terminals with QPSK $\frac{1}{2}$
Number of subscriber terminals in Queue_B and selected MCS	8 terminals with QPSK $\frac{1}{2}$	5 terminals with QPSK $\frac{1}{2}$	1 terminal with QPSK $\frac{1}{2}$	0
Total resource used in MBS zone (time slot) to maintain QoS level for Queue_A	1	1.5	3	4
Comments	Bad choice - most terminals are not given good MCS	Good - this could make a bigger group happy while keeping the resource usage low.	Moderate - A big group enjoy reasonable ok MCS but result in higher resource utilization.	Bad – not intelligent at all. Resource usage is high and all subscribers using lowest MCS.

Figure 7

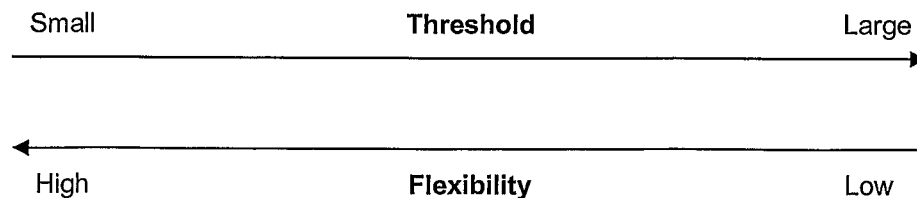
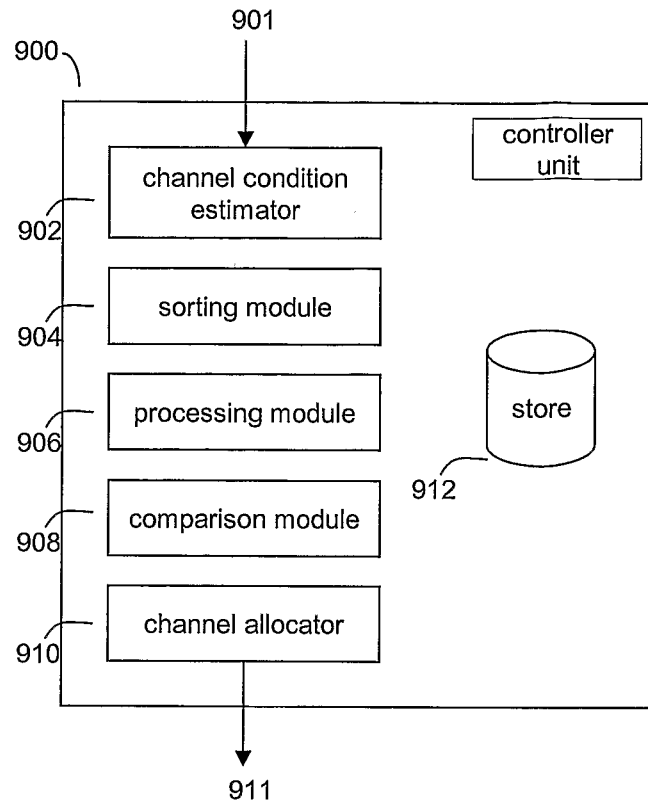


Figure 8

**Figure 9**