(57) Abstract: A mobile station selectively operates in quick paging mode (108) or in slotted paging mode (110). If the quality of the channel exceeds a threshold (106), then the mobile station operated in quick paging mode; otherwise in slotted paging mode. The mobile station measures channel quality by measuring various quality metrics (112-120) made during several previous pages (124), preferably over a period of about ten seconds (128). The quality metrics, and the previous pages, are preferably all given equal weight (122, 126).
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PAGING MODE SELECTION
BASED ON CHANNEL QUALITY

BACKGROUND OF THE INVENTION

Technical Field

[1001]  This invention relates to wireless communication between a base station and a mobile station, and has particular relation to selecting whether the mobile station should operate in quick paging mode or in slotted paging mode.

Background Art

[1002]  A wireless communications system includes base stations and mobile stations. Communication often needs to be established from a base station to a mobile station, such as when a call needs to be placed to a cellular or PCS telephone. In this case, the base station typically transmits a paging message, inviting a particular mobile station to respond. The mobile station, upon receiving the page, makes the appropriate response, and the process of setting up the call begins. The page does not include just a binary signal which indicates whether a call is on the way, but also includes considerable additional information to ensure that the correct mobile station (and only the correct mobile station) will respond.

[1003]  Mobile stations are typically battery-operated. Battery life is shortened if the mobile station is turned on all the time, waiting for a page. To avoid this problem, the wireless communications system divides time into slots. Each slot is very brief, only 80 msec, and is typically repeated after a slot cycle of 1.28 seconds, assuming that the slot cycle index is 0. In some applications, the slot cycle index is 1, 2, etc., and the slot cycle is doubled, quadrupled, etc. The base station assigns each mobile station to a particular slot, and transmits pages only during that slot. The mobile station therefore needs to wake up only
during that slot, and need not drain its battery during the remainder of the time. This process is called “slotted paging”.

[1004] A process known as “quick paging” has improved upon slotted paging. Quick paging does not require that the mobile station turn on for the entire slot, prepared to receive a page if a page is transmitted. Instead, a short time before the slot, the base station transmits an extremely brief “quick page”. The quick page is a binary signal which indicates whether or not a slotted page will be present in the next slot. The mobile phone turns on just long enough to receive the quick page. Occasionally the quick page indicates that a slotted page follows. In this case, the mobile station gets ready to receive and decode the slotted page.

Most of the time, however, the quick page indicates that no slotted page follows. In this case, the mobile station goes back to sleep and conserves precious battery power.

[1005] Quick paging extends battery life (in comparison with slotted paging) only when the mobile station is in standby mode. It does not affect battery life when the mobile station is actually in a call with the base station, and it adds complexity to the mobile station. Quick paging mode has therefore not been made mandatory for a particular mobile station even though the base station is using this mode. The mobile station can simply sleep through every quick page and wake up for every slotted page. If the base station has not transmitted a slotted page for that mobile station during that slot, then the mobile station will recognize this fact and simply go to sleep until the next slot. Thus, quick paging is seen to be backward compatible. An old mobile station (manufactured before quick paging became the standard) can function well with a new base station (which is using quick paging).

**SUMMARY OF THE INVENTION**

[1006] Applicants have noticed an undesirable side effect of quick paging: if the paging channel is noisy, then quick paging actually reduces battery life. This unexpected side effect comes about from an important requirement placed on the quick page system: there must be a very low probability that a quick page will be missed. This is not generally considered to be a problem, since the paging signal (whether quick page or conventional slotted page) is generally much stronger than the communication signal which is used to actually carry the call. However, there will be times when the channel over which the page is transmitted (the paging channel) is contaminated with considerable noise. When this happens, the mobile
station will be unable to assure itself that the quick page is absent, and will stay on to receive a possible slotted page.

[1007] The slot for the slotted page is much longer than the interval set for the quick page, and carries information much more reliably. This extra length is both good and bad. Most of the time this slotted page will be absent. The extra length allows the mobile station to assure itself that no valid slotted page was present during the slot. However, the extra length also means that the mobile station will have consumed extra battery life in making this assurance. Worse, the mobile station will also have consumed valuable battery life in attempting to receive a quick page. A quick page which has been sent over a noisy channel is essentially worthless. It would have been better, in the presence of such noise, if the mobile station had simply operated in slotted paging mode (that is, without the quick page). Fortunately, the mobile station has had some experience with the noisiness of the paging channel, and can use that experience to decide whether to operate in quick paging mode or in conventional slotted paging mode.

[1008] In its broadest aspect, a method is shown for a mobile station selectively operating in quick page mode or in slotted page mode, wherein:

the method includes the step of the mobile station receiving (102) a page during at least one previous slot cycle; and

the method is characterized in that it further includes the steps of:

the mobile station making a deciding quality measurement (104) of the previous page; and

the mobile station operating in quick page mode (108) if the quality measurement exceeds a threshold (106) and operating in slotted page mode (110) if the quality measurement does not exceed the threshold.

BRIEF DESCRIPTION OF THE DRAWINGS

[1009] FIG. 1 is a flow chart of a method for selecting the paging mode base on channel quality.

[1010] FIG. 2 is a block diagram of apparatus using the method of FIG. 1.
DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[1011] FIG. 1 is a flow chart of a method for selecting the paging mode base on channel quality. The quick page typically has two quick page indicators, each only a fraction of a millisecond long, spaced apart, and set a little before the slot. If the first quick page indicator clearly indicates that no slotted page follows, then the mobile station immediately goes back to sleep. If the first indicator is unclear, or clearly indicates that a slotted page follows, then the mobile station stays awake for the second indicator. If the second quick page indicator clearly indicates that no slotted page follows, then the mobile station immediately goes back to sleep. If the second indicator is unclear, or clearly indicates that a slotted page follows, then the mobile station stays awake for the slot. If either the first or the second indicator indicates that a page follows in the slot, then the mobile station stays awake for the page.

[1012] When the mobile station wakes up for a quick page indicator, a searcher searches for and finds a pilot signal. In the course of doing so, the searcher measures the energy of the pilot signal. After it has demodulated the pilot signal, the mobile station has an estimate of the strength of the pilot signal, a signal which is always present, even when no indicator or page is being transmitted. The searcher energy and the pilot strength estimate are each good measurements of the quality of the paging channel. As noted above, the quick page has two quick page indicators, each of which produces a measurement of searcher energy and of pilot strength estimate. The mobile station, having received both (or all four) measurements of the pilot channel quality, can decide whether to operate in quick paging mode or in conventional slotted paging mode.

[1013] There will be times when the quick page is insufficient to assure the mobile station that no slotted page follows. In this situation, the mobile station stays awake for the slot, and decodes whatever signal it receives. If the received signal really is a page, then the mobile station leaves paging mode and starts to take the call. Even when the received signal in not a page, however, the mobile station decodes the signal, and the process of decoding the signal generates a Received Signal Strength Indication, or RSSI. The RSSI is a much more precise number than are either of the quick page measurements (searcher energy and pilot strength estimate), since the slot is so much longer than the quick page interval. The RSSI, when present, gives to the mobile station a fifth measurement of the quality of the paging channel.
When the mobile station has received only the first of the quick page indicators, it has two measurements (searcher energy and pilot strength estimate) of paging channel quality. If it receives both of the quick page indicators, it has four measurements of paging channel quality. If it decodes the slotted page, it has a fifth measurement (RSSI). How should these measurements be combined to produce an overall figure of merit?

Surprisingly, the best combination of measurements is to weigh all available measurements equally. The RSSI should not be given extra weight even though the RSSI was measured over a longer period of time, and even though the RSSI is more precise than any of the quick page measurements.

Of course, almost any weighting of measurements is better than ignoring the measurements and deciding blindly whether to operate in quick paging mode or slotted paging mode. The weighting could be dynamic, or the measurements could be combined in some other fashion, such as a nonlinear function. However, an equal weighting is better than any of other combination.

The mobile station is not limited to measurements made during the previous slot cycle. If measurements are available from several previous slot cycles, then the measurements from all such slot cycles can be combined to give a better estimate of the quality of the paging channel.

It might be thought that measurements from more recent slot cycles should be given greater weight than measurements from more remote slot cycles; an exponential weighting would seem natural. However, this is not the case. Equal weight should be given to measurements from all slot cycles over a reasonable period. Ten seconds (eight slot cycles, if the slot cycle index is 0) is the preferred period.

As before, almost any weighting (or other combination, such as a Markov chain) over several slot cycles is better than taking measurements over only the immediately preceding slot cycle. Also as before, however, an equal weighting is better than any other combination.

It is not required that the mobile station consider pages -- whether quick, slotted, or both -- from only one base station. If several base stations are paging the mobile station, measurements from all available pages should be considered, the same as if they came from a single base station.
\([1021]\) It is thus seen that a mobile station may selectively operate in quick page mode or in slotted page mode. First, the mobile station receives (102) a page during at least one previous slot cycle. A plurality of previous slot cycles is preferred. Then, the mobile station makes a deciding quality measurement (104) of the previous page. The mobile station operates in quick page mode (108) if the quality measurement exceeds a threshold (106) and operates in slotted page mode (110) if the quality measurement does not exceed the threshold. Preferably, the deciding quality measurement is a combination of measurements selected from at least two of the following component quality measurements:

- searcher energy measured during a first page indicator (112);
- pilot strength measured during a first page indicator (114);
- searcher energy measured during a second page indicator (116);
- pilot strength measured during a second page indicator (118); and
- received signal strength indication of a slotted page (120).

Also preferably, the combination of the component quality measurements is an equal-weighted averaging (122) of the component quality measurements.

\([1022]\) As noted above, a plurality (124) of previous slot cycles is preferred. In this case, the deciding quality measurement should be a combination of page quality measurement of the pages of each of the plurality of previous slot cycles, preferably an equal-weighted averaging (126) of the plurality of previous slot page quality measurements. The previous slot cycles should last a total of about ten seconds (128).

\([1023]\) FIG. 2 is a block diagram (200) of apparatus using the method of FIG. 1. It is seen that a mobile station (208) should be structured to selectively operate in quick page mode (204) or in slotted page mode (206) with a base station (202). The mobile station should be structured to carry out any (and preferably all) of the forgoing methods, preferably be means of an integrated circuit.

**INDUSTRIAL APPLICATION**

\([1024]\) This invention is capable of exploitation in industry, and can be made and used, whenever it is desired for a mobile station, in a wireless communication system, to select between quick paging mode and slotted paging mode. The individual components of the
apparatus and method shown herein, taken separate and apart from one another, may be entirely conventional, it being their combination that is claimed as the invention.

[1025] While various modes of apparatus and method have been described, the true spirit and scope of the invention are not limited thereto, but are limited only by the following claims and their equivalents, and such are claimed as the invention.
CLAIMS

1. A method for a mobile station selectively operating in quick page mode or in slotted page mode, wherein:
   (a) the method includes the step of the mobile station receiving (102) a page during at least one previous slot cycle; and
   (b) the method is characterized in that it further includes the steps of:
      (1) the mobile station making a deciding quality measurement (104) of a channel during the previous page; and
      (2) the mobile station operating in quick page mode (108) if the deciding quality measurement exceeds a threshold (106) and operating in slotted page mode (110) if the deciding quality measurement does not exceed the threshold.

2. The method of claim 1, characterized in that the deciding quality measurement is a combination of measurements selected from at least two of the following component quality measurements:
   (a) searcher energy measured during a first page indicator (112);
   (b) pilot strength measured during a first page indicator (114);
   (c) searcher energy measured during a second page indicator (116);
   (d) pilot strength measured during a second page indicator (118); and
   (e) received signal strength indication of a slotted page (120).

3. The method of claim 3, wherein the combination of the component quality measurements is an equal-weighted averaging (122) of the component quality measurements.
4. The method of claim 1, wherein:
   (a) the method includes the step of the mobile station receiving a page during a plurality
       (124) of previous slot cycles; and
   (b) the method is characterized in that the step of the mobile station making the
       deciding quality measurement further includes the steps of the mobile station:
       (1) making at least one channel quality measurement during each of the plurality of
           previous slot cycles; and
       (2) making the deciding quality measurement by combining the channel quality
           measurements made during the plurality of previous slot cycles.

5. The method of claim 4, wherein the combination of the page quality measurements is an
   equal-weighted averaging (126) of the channel quality measurements.

6. The method of claim 5, wherein the previous slot cycles last a total of about ten seconds
   (128).

7. The method of claim 4, wherein the previous slot cycles last a total of about ten seconds.

8. A mobile station (208) structured to selectively operate in quick page mode (204) or in
   slotted page mode (206), wherein:
   (a) the mobile station is structured to receive a page during at least one previous slot
       cycle; and
   (b) the mobile station is characterized in that it further includes an integrated circuit
       structured:
       (1) to make a deciding quality measurement of a channel during the previous page;
           and
       (2) to operate in quick page mode if the deciding quality measurement exceeds a
           threshold and operating in slotted page mode if the deciding quality
           measurement does not exceed the threshold.
9. The mobile station of claim 8, characterized in that it is structured to make the deciding
quality measurement as a combination of measurements selected from at least two of the
following component quality measurements:
(a) searcher energy measured during a first page indicator (112);
(b) pilot strength measured during a first page indicator (114);
(c) searcher energy measured during a second page indicator (116);
(d) pilot strength measured during a second page indicator (118); and
(e) received signal strength indication of a slotted page (120).

10. The mobile station of claim 9, wherein the combination of the component quality
measurements is an equal-weighted averaging of the component quality measurements.

11. The mobile station of claim 8, wherein:
(a) the mobile station is structured to receive a page during a plurality of previous slot
cycles; and
(b) the mobile station is characterized in that the mobile station is structured to make
the deciding quality measurement by:
(1) making at least one channel quality measurement during each of the plurality of
previous slot cycles; and
(2) making the deciding quality measurement by combining the channel quality
measurements made during the plurality of previous slot cycles.

12. The mobile station of claim 11, wherein the combination of the page quality
measurements is an equal-weighted averaging (126) of the page quality measurements.

13. The mobile station of claim 12, wherein the previous slot cycles last a total of about ten
seconds.

14. The mobile station of claim 11, wherein the previous slot cycles last a total of about ten
seconds.