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Location Determination Using Sequential Pattern Recognition

Technical Field

This invention relates to location determination using sequential pattern recognition

5 and refers particularly, though not exclusively, to location determination using mobile device and base transceiver station identifiers for sequential pattern recognition.

Reference to Related Applications

Reference is made to our earlier Singapore patent application number 200605787-1 filed 28

10 August 2006 for "Mobile Detection of a Mobile Device " (our "earlier application"), the contents of which are hereby incorporated by reference as if disclosed herein in their entirety.

Definitions

Throughout this specification a reference to a mobile device is to be taken as including a

15 reference to a mobile/cellular telephone device, or any other device that is capable of mobile/cellular telecommunication including, but not limited to, personal digital assistants, a push email device such as, for example, a "Blackberry", tablet computers, notebook computers laptop computers, and similar devices.

20 Background

Location technology using GSM signals have been tested in various forms (see attached document). However, virtually all these technologies use the concept of time difference techniques, relying on GSM network services provided by vendors such as, for example, Nokia, Siemens and Sony Ericsson.

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In our earlier application there is disclosed a location technology that uses observations of GSM signals at the mobile device to determine a location of the mobile device. The technology works independently without access to the network's backend services. Computation of the location can be done locally at the mobile device or at the server end.



This is not able to track the location of a mobile device when moving across several cells, as for example, when a mobile device is in a car moving on a freeway.

5 Summary

According to a preferred aspect there is provided a method for location determination using sequential pattern recognition. The method comprises determining a specific sequence of identifiers of a plurality of base transceiver stations that control cells through which a mobile device has passed when travelling along a path. The specific sequence of identifiers of the plurality of base transceiver stations is compared with a look-up table stored in a database, the look-up table comprising all possible sequence of identifiers of base transceiver stations and a location for each of the sequence of identifiers of base transceiver stations. The location of the path is determined from the comparison.

All possible sequence of identifiers of base transceiver stations may be obtained by mapping all possible sequences of identifiers of base transceiver stations for each of the locations; and recording all the possible sequences of identifiers of base transceiver stations and the location of each of the possible sequence of identifiers of base transceiver stations in the database. The mapping may be at different speeds.

The specific sequence of identifiers of the plurality of base transceiver stations is for active base transceiver stations; and may be for a set of possible locations. Each location may comprise a plurality of paths, and each path may comprise a plurality of sub-paths.

A unique identifier of each of the plurality of base transceiver stations may be given to the mobile device as it enters each of the cells controlled by each of the plurality of base transceiver stations. The unique identifiers of each of the plurality of base transceiver stations may be stored sequentially in the mobile device to form the specific sequence of identifiers of the plurality of base transceiver stations. The storing may be in a manner selected from: in a SIM

card of the mobile device, in a smart card of the mobile device, and in a CPU of the mobile device.

5 A unique identifier of the mobile device may be sent to the database by each of the plurality of base transceiver stations in the order in which their cells are entered as the mobile device moves along the path. Alternatively or additionally, the specific sequence of identifiers of each of the plurality of base transceiver stations as stored in the mobile device may be sent to the database by the mobile device. The specific sequence of identifiers of each of the plurality of base transceiver stations may be sent by a wireless connection including at least one of: SMS, 10 MMS, and GPRS. The sending may be at preset intervals selected from: time, at regular intervals of time, at predetermined intervals of time, after a predetermined number of base transceiver station identifiers have been recorded, and when a message size is at a certain limit. The specific sequence of identifiers of each of the plurality of base transceiver stations may be determined by a server as a result of data received from one or more of the plurality of base 15 transceiver stations.

According to a second preferred aspect there is provided a method for location determination using sequential pattern recognition. The method comprises determining a specific set of identifiers of a plurality of base transceiver stations that control cells in a zone in which a mobile 20 device is located. The specific set of identifiers of the plurality of base transceiver stations is compared with a look-up table stored in a database, the look-up table comprising all possible sets of identifiers of base transceiver stations and a location for each of the sets of identifiers of base transceiver stations. A characteristic of the zone is determined from the comparison.

25 The characteristic of the zone may be selected from: the specific set of identifiers of the plurality of base transceiver stations, and an identifier of a location of the zone. All possible sets of identifiers of base transceiver stations are obtained by mapping all possible sets of identifiers of base transceiver stations for each of the locations; and recording all the possible sets of

identifiers of base transceiver stations and the location of each of the possible sets of identifiers of base transceiver stations in the database.

5 The specific set of identifiers of the plurality of base transceiver stations may be for active base transceiver stations. A unique identifier of each of the plurality of base transceiver stations may be sent to the mobile device. The unique identifier of each of the plurality of base transceiver stations may be sent to the mobile device as it enters each of the cells controlled by each of the plurality of base transceiver stations. The unique identifiers of each of the plurality of base transceiver stations may be stored in the mobile device to form the specific set of identifiers of
10 the plurality of base transceiver stations. The storing may be in a manner selected from: in a SIM card of the mobile device, in a smart card of the mobile device, and in a CPU of the mobile device.

15 A unique identifier of the mobile device may be sent to the database by each of the plurality of base transceiver stations in the order in which their cells are entered as the mobile device enters the zone.

The specific set of identifiers of each of the plurality of base transceiver stations as stored in the mobile device may be sent to the database by the mobile device. The specific set of identifiers
20 of each of the plurality of base transceiver stations may be sent by a wireless connection including at least one of: SMS, MMS, and GPRS. The sending may be at preset intervals selected from: time, at regular intervals of time, at predetermined intervals of time, after a predetermined number of base transceiver station identifiers have been recorded, and when a message size is at a certain limit.

25 The look-up table may be used by the mobile device to translate a selected zone into a set of base transceiver identifiers. The set of base transceiver station identifiers may be set on or transferred to the mobile device. If an observed base transceiver station identifier of the mobile

device is in the set of base transceiver station identifiers another application of the mobile device may be started. The zone may be used to provide caller location identification.

Brief Description of the Drawings

5 In order that the invention may be fully understood and readily put into practical effect there shall now be described by way of non-limitative example only preferred embodiments of the present invention, the description being with reference to the accompanying illustrative drawings.

10 In the drawings:

Figure 1 is a schematic representation of an observed sequence of base transceiver stations in a specific direction;

Figure 2 is a schematic representation of a number of base transceiver stations in a specific zone;

15 Figure 3 is a flow chart for the operation of the exemplary embodiment of Figure 1;

Figure 4 is a flow chart for the operation of the exemplary embodiment of Figure 2; and

Figure 5 is a flow chart for the operation of another exemplary embodiment.

Detailed Description of the Exemplary Embodiments

20 The exemplary embodiments are able to use observations on the mobile device or SIM/Smart card of the mobile device to determine the state of a mobile device, and are able to detect if the mobile device is in motion or is stationary. GSM signals may be observed on a mobile device SIM/Smartcard. The SIM/Smart card is becoming more powerful and is capable of performing limited, less CPU intensive, operations locally. For mobile devices that have a local CPU,
25 observable parameters may be processed instantaneously on the mobile device. For mobile devices with limited processing capability, the observed parameters may be transmitted to a server for processing.

The exemplary embodiments are suitable for use in location-based services such as, for example:

- traffic management,
- road fleet management (e.g. taxis, lorries, trucks, couriers, police, police vehicles,
- 5 ambulances, fire brigade vehicles),
- location advertising,
- security (e.g. in cars when they are stolen),
- medical alerts,
- monitoring or tracking (e.g. if workers have left the office), and
- 10 road-toll systems.

The technique allows observable parameters to be translated into location information which then can be utilized for such location-based services.

15 The exemplary embodiments may:

1. be implemented as a client on a mobile device or SIM/smart card, or as an embedded application that monitors network activity and processes the information;
2. use ground survey and calibration to obtain a database of information from which locations are determined;
- 20 3. use a control application that allows settings (e.g. password protection, detection sensitivity, Internet Protocol server for communication, send messages, and so forth) to be changed wirelessly;
4. use an ancillary application that allows wireless downloads of the necessary modules to be able to implement the service; and
- 25 5. allow a backend server to implement the service in conjunction with network operators. Access to network services will be required for this to be achieved.

As shown in Figures 1 and 3, there is provided a method to identify that a mobile device 100 is moving along a particular road segment 102. Adjacent the road segment 102 are a series of

base transceiver stations: a first base transceiver station 104, a second base transceiver station 106, a third base transceiver station 108 and a fourth base transceiver station 110. Each of the base transceiver stations 104, 106, 108 and 110 has a unique identifier that is communicated to the mobile device 100 during the handshake procedure when the mobile device 100 enters the cell controlled by the respective base transceiver station. The number of base transceiver stations is not limited to four and may be any required, desired or necessary number. However, it is preferred that there be at least three to be able to provide unique sequences of base transceiver station identifiers.

10 This method uses the way which the mobile device 100 detects which of the base transceiver stations 104, 106, 108 and 110 is active, and how that changes, as the mobile device 100 moves along the road segment 102. As the mobile device 100 traverses the road segment 102, it traces out a sequence of active cells each of which is controlled by one of the base transceiver stations 104, 106, 108 and 110. As cells may overlap, at any one time the mobile device 100 may be in one or more active cells.

Depending on the length of the road segment 102 and the density of base transceiver stations 104, 106, 108 and 110 around the road segment 102, a unique sequence, or several possible unique sequences, of base transceiver stations may be identified for each road segment 102.

20 The potential sequences are unique for different speeds (or lack of speed, such as when at a standstill as in traffic jams) and differs when traversing in different directions. Speed is a factor as if the area of a particular cell relevant for a specific path is quite small, there may be insufficient time for the handshake procedure to take place before the cell is exited, and thus the cell identifier will not appear in the unique sequence of cell identifiers through which the mobile device 100 has passed.

As can be seen for movement along a first path 102a in one direction (given on Figure 1 as "forwards") the sequence of active cells from the base transceiver stations 104, 106, 108 and 110 is 1, 3, 4, 2 representing base transceiver stations 104, 108, 110 and 106 respectively. The

unique sequence means that when a similar sequence is observed, it can be determined that the mobile device 100 has traversed the segment 102. This makes the sequential pattern very useful for traffic management, and especially for road tolling.

- 5 Each of the base transceiver stations 104, 106, 108 and 110 is operatively connected to a server 140 over a telecommunications network (not shown). Also, the mobile device 100 is operatively connected to server 140 via the base transceiver stations 104, 106, 108 and 110.

The server 140 includes a database 142. Database 142 contains details of all possible
10 sequences of base transceiver stations and their corresponding location. With the database 142 of sequences of identifiers of base transceiver stations and the possible locations for that sequence, it is possible to determine on which segment a mobile device has been or is traversing, given an observed sequence.

15 For a traverse on a second path b in the opposite direction (given as “backward” on Figure 1) the resultant sequence is different: 4, 2, 3 and 1 representing base transceiver stations 110, 106, 108 and 104 respectively. This is different to the sequence in the forwards direction on path a.

20 In cases where a particular road segment does not have a unique sequence, it is possible to identify all the segments that have this sequence. As such, while it is not possible to determine if a particular segment has been traversed, it is possible to determine that a one of a set of possible road segments has been traversed. For example, a mobile device in a vehicle traveling
25 on an elevated expressway and a different mobile device in a different vehicle traveling on a normal road beneath the elevated expressway may have exactly the same sequence of base transceiver stations. In such a case the sequence may be able to be used in ways that do not require a unique signature.

To establish the necessary data, each road segment to be identified is surveyed by traversing the segment in both directions to determine the cell sequence, at varying speeds, and the data recorded in server 140 and database 142 (301). For each sub-path a, b the cells that are within coverage are determined (302). The unique identifier of each of the base transceiving stations for each of the cells is also recorded (303). The possible combination of sequences is then determined (304) and the possible sets of sequences are generated (305). A check is then conducted for nearby segments to ensure that similar sequences are not observed in those nearby segments (306). If it is not possible to have a unique sequence (307), one or more additional base transceiver station may have to be erected to create the unique sequence (308).
10 If the sequence is unique, the information is then stored in the database 142 (309).

When a mobile device 100 traverses a road segment 102 a or b (310), the unique identifier of the mobile device 100 is given to each of the base transceiver stations 104, 106, 108 and 110 during the handshake procedure as it enters the cell of the relevant base transceiving station, and the unique identifier of each of the base transceiver stations 104, 106, 108 and 110 is given to the mobile device 100 during the handshake procedure as it enters the cell of the relevant base transceiving station 104, 106, 108 and 110 (311). The sequence of identifiers of base transceiver stations 104, 106, 108 and 110 relevant for mobile device 100 as it traverses the road segment may be recorded in one or more of a number of ways:

20 by being recorded in the SIM/Smart card of mobile device 100, and/or in the CPU of mobile device 100 (312),

the mobile device 100 identifier is sent to the server 140 by the base transceiver stations 104, 106, 108, 110 in the order in which their cells are entered as the mobile device 100 moves along segment 102 (313).

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As such, the sequence of identifiers of base transceiver stations 104, 106, 108, 110 of the mobile device 100 is:

sent to server 140 by the mobile device 100 by SMS, MMS, GPRS or any other wireless connection system (316). This may be at preset intervals determined by time (i.e. is sent at

regular, predetermined intervals of time) and/or after a predetermined number of cell identifiers have been recorded and/or when the message size is at a certain limit (for example, the maximum size of an SMS message is 160 characters); or otherwise as required or desired; and/or

5 is determined by the server 140 as a result of the data received from one or more of the base transceiver stations 104, 106, 108 and 110. The base transceiver station identifier and the mobile device identifier are extracted from the received data (314) by the server 140. Other data (e.g. time) may also be extracted by server 140. In this way the server 140 records the sequence of base transceiver station identifiers by the mobile device identifier (315).

10 The sequence will be received at the server 140 and stored in the database 142 (317). The server 140 then determines the movement and location of the mobile device 100 based on the sequence of cell identifiers as received by it when compared with those retrieved from the database 142 (318). From the server 140 and database 142 it may be accessed when and as
15 required by suitably authorized personnel (319).

In Figure 2 the same reference numerals are used for like components but with the prefix number changed from "1" to "2". As shown in Figures 2 and 4, the method is not as effective for non-linear sequencing. For a zone such as zone 230, the sequences of identifiers of the base
20 transceiving stations are less likely to be unique. However, a set 112 of identifiers of the base transceiver stations having a cell in which the mobile device 200 is located can be obtained. As such if a specific set 212 of base transceiver station identifiers is observed it is possible to determine that the mobile device 200 is in zone 230. The zone 230 would be significantly smaller than the size of a single cell 214, 216, 218 and 220 of the base transceiver stations 204,
25 206, 208, 210 respectively as the zone 230 represents the area that is common to the cells 214, 216, 218 and 220 of the observed base transceiver stations 204, 206, 208 and 210.

Again, to establish the necessary data, each zone to be identified is surveyed by traversing the zone in many directions to determine the cell sequence, at varying speeds, and the data

recorded in server 240 and database 242 (401). The unique identifier of each of the base transceiving stations for each of the cells is also recorded (402). The possible combination of identifiers is then determined (403) and the possible sets of combinations are generated (404) for all locations within each zone 230. A check is then conducted for nearby zones to ensure
5 that similar combinations are not observed in those nearby zones (405). If it is not possible to have a unique combination (406), one or more additional base transceiver station may have to be erected to create the unique combination (407). If it is a unique set, the information is then stored in the database 242 (408).

10 When the mobile device 200 enters the zone 230 (409), the unique identifier of the mobile device 200 is given to each of the base transceiver stations 204, 206, 208 and 210 during the handshake procedure as it enters the cell of the relevant base transceiving station 204, 206, 208 and 210 and the unique identifier of each of the base transceiver stations 204, 206, 208 and 210 is given to the mobile device 200 during the handshake procedure as it enters the cell
15 of the relevant base transceiving station 204, 206, 208 and 210 (410). The combination of base transceiver stations 204, 206, 208 and 210 of mobile device 200 in the zone 230 may be recorded in one or more of a number of ways:

by being recorded in the SIM/Smart card of mobile device 200, and/or in the CPU of mobile device 200 (411),

20 the mobile device 200 identifier is sent to the server 240 by the base transceiver stations 204, 206, 208, 210 as the mobile device 200 enters the zone 230 (412).

As such, the sequence of identifiers of base transceiver stations 204, 206, 208, 210 of the mobile device 200 is:

25 sent to server 240 by the mobile device 200 by SMS, MMS, GPRS or any other wireless connection system (415). This may be at preset intervals determined by time (i.e. is sent at regular, predetermined intervals of time) and/or after a predetermined number of cell identifiers have been recorded and/or when the message size is at a certain limit (for example, the maximum size of an SMS message is 160 characters); or otherwise as required or desired;

and/or

is determined by the server 240 as a result of the data received from one or more of the base transceiver stations 204, 206, 208 and 210. The base transceiver station identifier and the mobile device identifier are extracted from the received data (413) by the server 240. Other data
5 (e.g. time) may also be extracted by server 240. In this way the server 240 records the combination of base transceiver station identifiers by the mobile device identifier (414).

The sequence will be received at the server 240 and stored in the database 242 (416). The server 240 then determines the movement and location of the mobile device 200 based on the
10 sequence of cell identifiers as received by it when compared with those retrieved from the database 242 (417). From the server 240 and database 242 it may be accessed when and as required by suitably authorized personnel (318).

As is shown in Figure 5, to provide a capability to make a device location-aware, for location-
15 based service applications, it may be possible to make a device "location sensitive". For example, the user can use a backend application (e.g. web-based application) or an application on the mobile device to the mobile device location sensitive when in a particular zone or area. After selecting the application on the mobile device (501) the identifiers of the base transceiver stations relevant for the locations are determined, (502) and a lookup table is used to translate
20 the selected zone into a set of base transceiver stations (503). For example, a particular location may have base transceiver stations 245, 7635, 7652, 4368, 79512, 34098. The base transceiver station data set is then transferred to or set on the mobile device or its SIM card (504). The application on the mobile device checks its current observed base transceiver station against this data set (505). If it is a member of the dataset (506), the mobile device is within the
25 selected zone (507). The dataset (i.e. set of base transceiver station identifiers and/or the identity of the zone) is information may then be used to start another application such as, for example, one that can look for promotions in the selected zone. If not a member of the dataset, it is outside the zone (508).

To provide a caller location service and/or caller location alerts, and as most mobile devices currently have a caller-identification function, the location-aware capability can be used so that a location identifier can be provided when a call is answered. For example, when answering a call to a mobile device, the mobile device responding to the call will display, for example: "John
5 calling from CentrePoint"

Whilst there has been described in the foregoing description preferred embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations in details of design, construction and/or operation may be made without departing
10 from the present invention.

The Claims

1. A method for location determination using sequential pattern recognition, the method comprising:
 - determining a specific sequence of identifiers of a plurality of base transceiver stations that control cells through which a mobile device has passed when travelling along a path;
 - comparing the specific sequence of identifiers of a plurality of base transceiver stations with a look-up table stored in a database, the look-up table comprising all possible sequence of identifiers of base transceiver stations and a location for each of the sequence of identifiers of base transceiver stations; and
 - determining the location of the path from the comparison.
2. A method as claimed in claim 1, wherein all possible sequence of identifiers of base transceiver stations are obtained by:
 - mapping all possible sequences of identifiers of base transceiver stations for each of the locations; and
 - recording all the possible sequences of identifiers of base transceiver stations and the location of each of the possible sequence of identifiers of base transceiver stations in the database.
3. A method as claimed in claim 2, wherein the mapping is at different speeds.
4. A method as claimed in any one of claims 1 to 3, wherein the specific sequence of identifiers of a plurality of base transceiver stations is for active base transceiver stations.
5. A method as claimed in any one of claims 1 to 4, wherein the specific sequence of identifiers of a plurality of base transceiver stations is for a set of possible locations.
6. A method as claimed in any one of claims 1 to 5, wherein each location comprises a plurality of paths, and each path comprises a plurality of sub-paths.
7. A method as claimed in any one of claims 1 to 6, wherein a unique identifier of each of the plurality of base transceiver stations is given to the mobile device as it enters each of the cells controlled by each of the plurality of base transceiver stations.

8. A method as claimed in claim 7, wherein the unique identifiers of each of the plurality of base transceiver stations are stored sequentially in the mobile device to form the specific sequence of identifiers of the plurality of base transceiver stations, the storing being in a manner selected from the group consisting of: in a SIM card of the mobile device, in a smart card of the mobile device, and in a CPU of the mobile device.
9. A method as claimed in any one of claims 1 to 8, wherein a unique identifier of the mobile device is sent to the database by each of the plurality of base transceiver stations in the order in which their cells are entered as the mobile device moves along the path.
10. A method as claimed in any one of claims 1 to 8, wherein the specific sequence of identifiers of each of the plurality of base transceiver stations as stored in the mobile device is sent to the database by the mobile device.
11. A method as claimed in claim 10, wherein the specific sequence of identifiers of each of the plurality of base transceiver stations is sent by a wireless connection including at least one selected from the group consisting of: SMS, MMS, and GPRS.
12. A method as claimed in claim 10 or claim 11, wherein the sending is at preset intervals selected from the group consisting of: time, at regular intervals of time, at predetermined intervals of time, after a predetermined number of base transceiver station identifiers have been recorded, and when a message size is at a certain limit.
13. A method as claimed in claim 9, wherein the specific sequence of identifiers of each of the plurality of base transceiver stations is determined by a server as a result of data received from one or more of the plurality of base transceiver stations.
14. A method for location determination using sequential pattern recognition, the method comprising:

determining a specific set of identifiers of a plurality of base transceiver stations that control cells in a zone in which a mobile device is located;

comparing the specific set of identifiers of a plurality of base transceiver stations with a look-up table stored in a database, the look-up table comprising all possible sets of identifiers of base transceiver stations and a location for each of the sets of identifiers of base transceiver stations; and

5 determining a characteristic of the zone from the comparison.

15. A method as claimed in claim 14, wherein the characteristic of the zone is selected from the group consisting of: the specific set of identifiers of the plurality of base transceiver stations, and an identifier of a location of the zone.

16. A method as claimed in claim 14 or claim 15, wherein all possible sets of identifiers
10 of base transceiver stations are obtained by:

 mapping all possible sets of identifiers of base transceiver stations for each of the locations; and

 recording all the possible sets of identifiers of base transceiver stations and the location of each of the possible sets of identifiers of base transceiver stations in the
15 database.

17. A method as claimed in any one of claims 14 to 16, wherein the specific set of identifiers of the plurality of base transceiver stations is for active base transceiver stations.

18. A method as claimed in any one of claims 14 to 17, wherein a unique identifier of
20 each of the plurality of base transceiver stations is sent to the mobile device.

19. A method as claimed in claim 18, wherein the unique identifier of each of the plurality of base transceiver stations is sent to the mobile device as it enters each of the cells controlled by each of the plurality of base transceiver stations.

20. A method as claimed in claim 18 or claim 19, wherein the unique identifiers of each
25 of the plurality of base transceiver stations are stored in the mobile device to form the specific set of identifiers of the plurality of base transceiver stations, the storing being in a manner selected from the group consisting of: in a SIM card of the mobile device, in a smart card of the mobile device, and in a CPU of the mobile device.

21. A method as claimed in any one of claims 14 to 20, wherein a unique identifier of the mobile device is sent to the database by each of the plurality of base transceiver stations in the order in which their cells are entered as the mobile device enters the zone.
- 5 22. A method as claimed in any one of claims 14 to 20, wherein the specific set of identifiers of each of the plurality of base transceiver stations as stored in the mobile device is sent to the database by the mobile device.
23. A method as claimed in claim 22, wherein the specific set of identifiers of each of the plurality of base transceiver stations is sent by a wireless connection including
10 at least one selected from the group consisting of: SMS, MMS, and GPRS.
24. A method as claimed in claim 22 or claim 23, wherein the sending is at preset intervals selected from the group consisting of: time, at regular intervals of time, at predetermined intervals of time, after a predetermined number of base transceiver station identifiers have been recorded, and when a message size is at a certain
15 limit.
25. A method as claimed in any one of claims 14 to 24, wherein the look-up table is used by the mobile device to translate a selected zone into a set of base transceiver identifiers, the set of base transceiver station identifiers being set on or transferred to the mobile device.
- 20 26. A method as claimed in claim 25, wherein if an observed base transceiver station identifier of the mobile device is in the set of base transceiver station identifiers another application of the mobile device is started.
27. A method as claimed in any one of claims 14 to 26, wherein the zone is used to provide caller location identification.
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