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Cell selection in border regions

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ABSTRACT

To prevent battery drain, 3GPP generally mandates that while under international roaming, a cellular device only scan for networks of the foreign country. For example, a US-based cellular device that is roaming in Canada will not generally scan for US service providers so long as it is being served by a Canadian service provider. This sometimes results in the unintended consequence of a cellular device in a border area physically in the home country but nevertheless stuck in international roaming.

Techniques of this disclosure provide a mechanism for a cellular device to recognize, through a process of self-learning, its presence in a border region. When a cellular device finds itself in a border region, it intelligently scans for preferred carriers in both home and foreign countries. When not close to a border region, the cellular device scans exclusively for carriers of the country it is currently physically present in.

KEYWORDS

- International roaming
- Mobile country code
- 3GPP
- Border regions cellular telephony
- Battery life

BACKGROUND

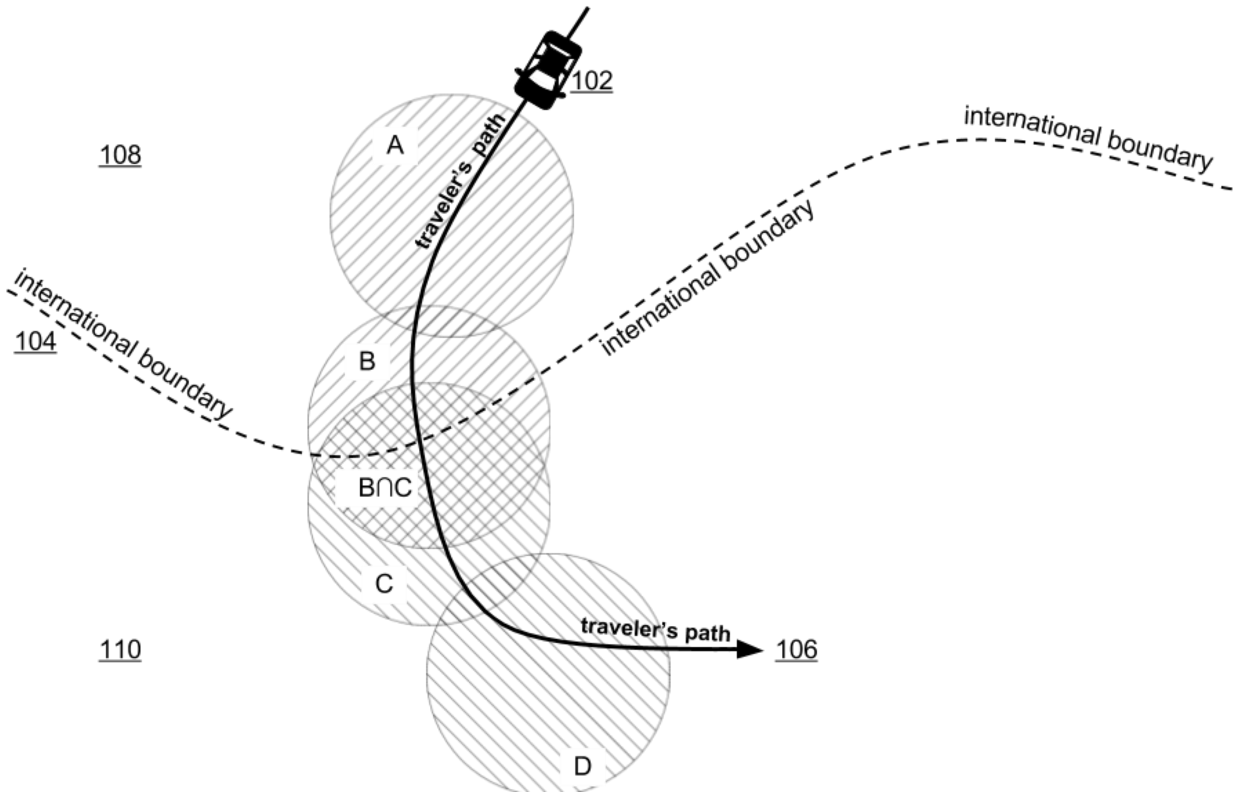

Fig. 1: A cellular-device bearing traveler crossing an international boundary

Fig. 1 illustrates a cellular-device bearing traveler (102) crossing an international boundary (104). The traveler's path (106) traverses regions served by base stations A, B, C, and D. Cells A and B belong to a service provider based in a first country (108), home to the traveler. Cells C and D belong to a service provider based in a second country (110), foreign to the traveler.

Cells B and C straddle the international boundary, so that there is a geographic region, denoted B∩C, wherein a traveler receives signals from service providers based in both countries. Although the present disclosure refers to the device being carried by the traveler as a cellular device, the device can be any type of device (e.g., smartphone, smartwatch, computer, tablet, or other portable device) capable of wireless communication with base stations using industry standards, e.g., 3GPP, LTE, etc.

In absence of the international boundary, the device is handed over between cells without the traveler incurring international roaming charges. For example, the traveler’s cellular device is handed over from cell A to cell B in the overlapping region of cell A and cell B, handed over from cell B to cell C in the region B∩C, etc. However, since the devices crosses an international boundary, signified by the handing over of the cellular device from home-carrier’s cell B to foreign carrier’s cell C, the traveler may incur international roaming charges. The roaming charges can continue to accrue so long as the device is the foreign country.

By conditions set forth in the 3GPP standard, once a cellular device is locked to a foreign cell, e.g., C or D in Fig. 1, it does not search to acquire a home-carrier’s cell or indeed any other domestic carrier. Once locked to a foreign service provider, the cellular device is only configured to search for other service providers based out of the foreign country. There are good reasons for such a requirement: for example, a device should not search for the home-country’s carriers when deep inside a foreign country, e.g., in a region where the home-country’s carriers are invisible. Such a search is futile and results in needless battery drain.

The aforesaid condition of the 3GPP standard results in certain peculiarities. For example, the user device may be stuck in international roaming even after the user returns to the home country, for example as long as the user is in the home-country side of a border area such as B∩C in Fig. 1. As another example, devices of users that live in a border area can acquire a foreign carrier and get stuck in international roaming without physically leaving the home country. Indeed, the only automatic way by which a home-country’s carrier is re-acquired upon a traveler's return to home country is for the device to lose contact with all foreign carriers, e.g., due to low signal strength, thereby triggering a full-band scan and re-acquisition of home carrier.

Users that live in border regions, e.g., region B∩C in Fig. 1, or travel frequently across the border, or that live in smaller countries with many nearby crisscrossing international boundaries, can thus incur international roaming charges even when in home country. Recognizing this quirk of the standard, some users often purposefully restart their cellular devices upon returning to their home countries.

A current solution to this problem is to maintain a list of neighboring countries. A cellular device is then configured to scan and acquire carriers based not only out of its home country, but also the neighbor(s) of the home country. This solution does ameliorate somewhat the issue of being stuck in international roaming. However, it introduces the problem of battery drain. A cellular device in a home (foreign) country can needlessly search for, acquire, and maintain a list of foreign (home) carriers with relatively distant signals. Also, the solution has the side effect of longer scan times whenever a device is in a country included in the neighboring country list, as the device now scans for preferred (domestic or neighboring foreign) networks more frequently.

DESCRIPTION

Per techniques of this disclosure, when a cellular device crosses an international boundary, e.g., is handed over from a home-country's carrier to a foreign carrier, the device notes the geographic region of handover as a region containing an international boundary. The notation includes the mobile country codes (MCC) of the countries straddling the border; the mobile network codes (MNC) of the domestic and foreign carriers detected in the region; the identities of the cells detected in the region; etc.

When a previously noted network code or cell identity is detected, the cellular device determines that it is in a border region, and expands the scope of the scan to domestic and foreign carriers as previously seen in that region. Similarly, if a cellular device determines that it is not in a border region, e.g., due to lack of visibility of cells or mobile network codes previously noted as being along the border, it limits its scan to exclusively domestic (if in home country) or exclusively foreign (if in a foreign country) service providers.

The techniques disclosed herein also provide for a forgetting factor, or hysteresis, during the scan process, such that as a cellular device moving from home to foreign country moves further away from the border, scans for home-country carriers are carried out less aggressively. Similarly, a cellular device that traverses the border in the foreign-to-home direction scans increasingly aggressively for home-country carriers.

Border Scan Table 202		
	Mobile Country Code	204
	Mobile Network Code	206
	Border_cell_list [ ]	208
	Radio access tech	210
	Cell-ID	212
	LAC	214
	TAC	216
	Border_mcc_list [ ]	218

Fig. 2: Example entry of a border scan table

Fig. 2 illustrates an example of an entry in the border scan table (202), which is a dynamic table created and updated by the cellular device when entering a border region, as detected, e.g., by the simultaneous presence of signals from domestic and foreign service providers. An entry of the border scan table includes:

- the mobile country code (204) of a service provider;
- the mobile network code (206) of the service provider;
- a list (208) of cells found along the border region, with each element of the list including the radio access technology, e.g., LTE, GSM, etc., a cell-identity (212) which includes a location area code (214), a tracking area code (216), or other means of identifying the cell and its location or region of coverage;
- a list (218) of mobile country codes of countries wherefrom service provider signals originate; etc.

Example

A traveler carrying a cellular device travels from the United States (MCC: 310) to Canada (MCC: 302). While in the US, the cellular device is served by a service provider with MNC 2xx operating an LTE network, whose border cell has LAC and TAC each set to 88. As the traveler crosses the border, the device gets handed over to a Canadian service provider with MNC 4xx operating a GSM network, whose border cell has LAC and TAC each set to 77. When the cellular device detects simultaneous signals from each country, it creates or updates the border scan table, which in this case is as shown in Fig. 3.

Border Scan Table	
Element [0]	
	Mobile Country Code: 310
	Mobile Network Code: 2xx
	Border_cell_list [ ]
	Radio access tech: LTE
	Cell-ID
	LAC: 88
	TAC: 88
	Border_mcc_list [3] = [302, -1, -1]
Element [1]	
	Mobile Country Code: 302
	Mobile Network Code: 4xx
	Border_cell_list [ ]
	Radio access tech: GSM
	Cell-ID
	LAC: 77
	TAC: 77
	Border_mcc_list [3] = [310, -1, -1]

Fig. 3: An example border scan table of a cellular device being taken from the US to Canada

Of note in the border scan table of Fig. 3 is the Border_mcc_list, present within each element of the border scan table and including (in this example) three elements, of which the first is the MCC of the neighbor country. The other two elements are set as null (−1) entries since there are no other countries along the border in this particular example.

A table as in Fig. 3 once created, when the cellular device detects at any time a cell with LAC and TAC set to 88, it knows that it is in a border region. It then starts scanning for foreign service providers. In particular, the device scans at least for the foreign service provider with MNC 4xx. Similarly, if the device detects a cell with LAC and TAC set to 77, it determines that it is nearing the home country. It then initiates scans for home-based carriers, in particular at least the home carrier with MNC 2xx.

To conserve memory, the length of the border scan table and of data structures within can be limited. Further, elements of the border scan table may be deleted or over-written if deemed out-of-date, or if data-structure size limits are exhausted. Further, scanning for home-based or foreign service providers is subject to hysteresis, or forgetting factor, such that as a device moves deeper into a foreign country, scans for domestic carriers are performed less aggressively, and as it returns closer to the border, scans for domestic carriers are performed more aggressively. The mechanism of hysteresis is illustrated in the scan procedure, illustrated in Fig. 4.

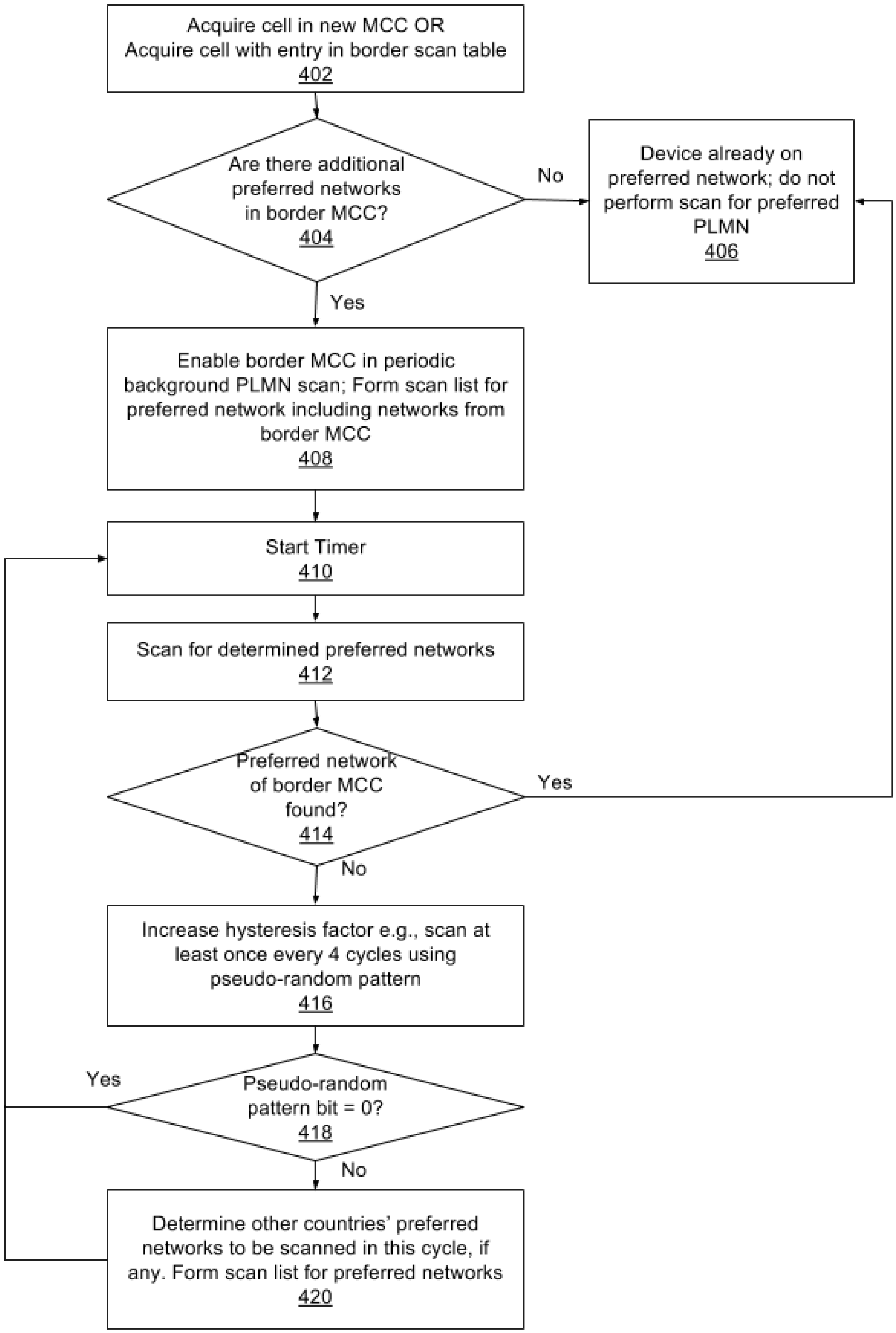

Fig. 4: Scan procedure

A cellular device acquires a cell in a new country (signified by a new MCC), or a cell that the border scan table indicates as a border cell (402). A check is performed to determine if there are networks along the border that are preferred over the one just acquired (404). If no preferred networks are found, then no preferred public land mobile network (PLMN) scan is performed (406).

If a more preferred network is found, then periodic background PLMN scan is enabled (408). A scan list for preferred networks is formed, including networks from border cells. A timer, e.g., of duration 30-45 seconds, is started (410). Within this timer duration, the device scans for the preferred network(s) (412). If, before the expiry of the timer, a preferred network, e.g., a home-country network, is found (414), the scan procedure returns to 402. If the timer expires without finding a preferred network, the hysteresis factor is increased (416) using, for example, a pseudo-random binary pattern.

Each logical one or zero in the binary pattern represents a timer duration. It is determined if the pseudo-random pattern bit corresponds to a logical zero (418). If the pseudo-random pattern bit corresponds to a logical zero, no foreign country networks are scanned and the scan procedure returns to start timer (410). If the pseudo-random pattern bit corresponds to a logical one, the device searches for service providers from all countries in the border scan table (420). Also, if a preferred foreign service provider is found (for example, the foreign service provider has a favorable roaming agreement with the user's domestic service provider), then no search is performed at a logical zero. However, even if already on a preferred foreign network, a binary one in the pseudo-random bit pattern triggers a search for a home-country service provider. The scan is performed once every few, e.g., four cycles. Each cycle corresponds to a group of bits.

The pseudo-random binary pattern is such that the density of logical ones is high towards the beginning (LSB-side) and decreases as one moves towards the end of the pattern (MSB-side). For example, such a pattern can be: 11010100100100100010001. This pattern of logical zeros and ones provides a mechanism for hysteresis (or forgetting factor), e.g., as the device user nears, then crosses, the border, the pseudo-random pattern comprises a greater number of ones, triggering a greater number of home- and foreign-country scans. As time elapses and the user moves further away from the border, the pseudo-random pattern comprises a greater number of zeros, thereby reducing the number of home-country scans and increasing the number of foreign-country scans that are performed.

CONCLUSION

Techniques of this disclosure provide a mechanism for a cellular device to determine that it is in a border region and intelligently select home-based or foreign-based carriers in a manner that reduces roaming charges and provides improved quality of service.