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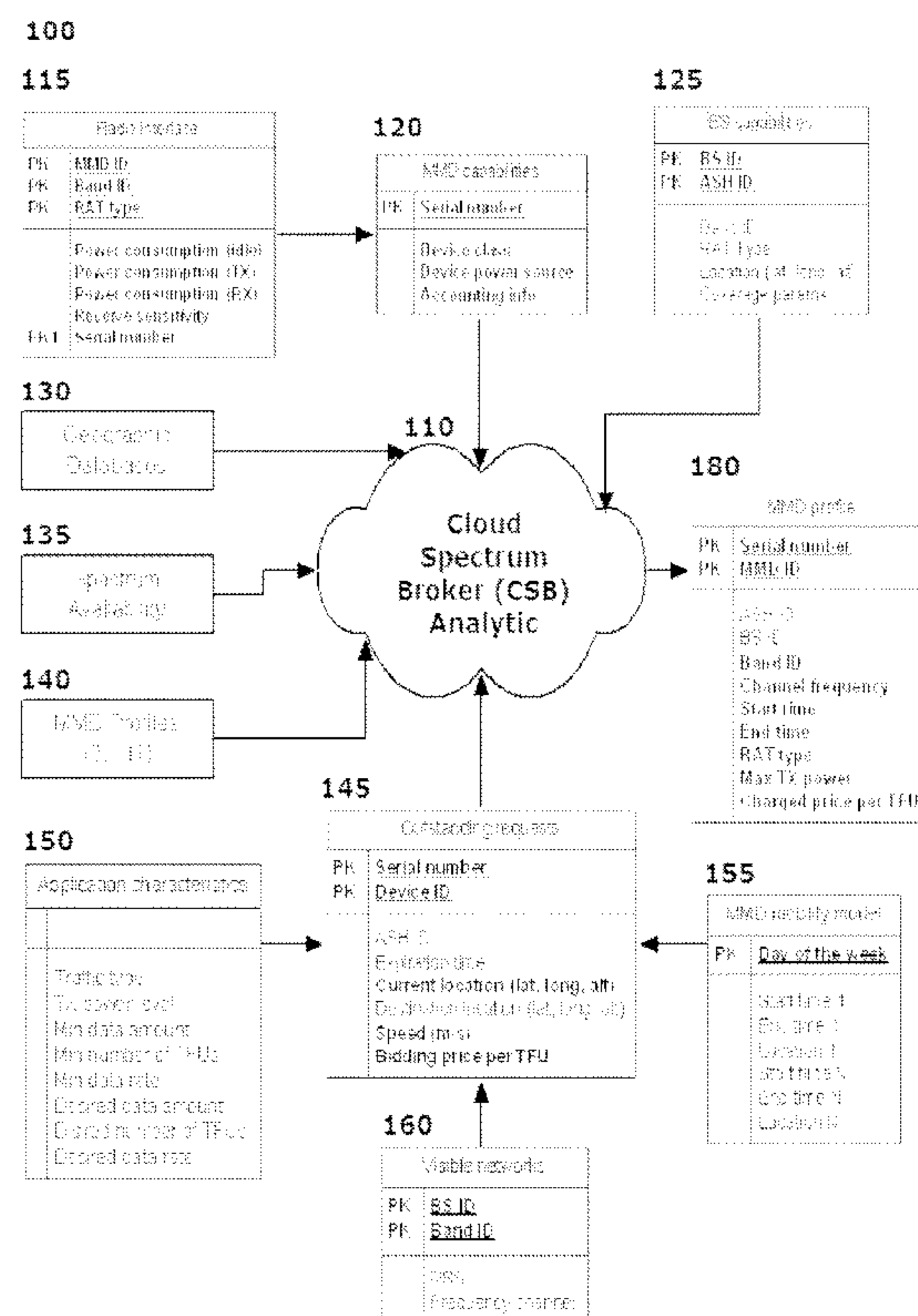


FIG. 1

(57) Abrégé/Abstract:

A system and method are provided for implementing a spectrum management analytics (SMA) algorithm that references a plurality of enumerated inputs to generate a set of output parameters for use in attempting to optimize spectrum. The SMA algorithm is a



(57) **Abrégé(suite)/Abstract(continued):**

part of a cloud spectrum broker (CSB) analytic. The CSB analytic provides for: (1) Managing CSS transactions involving transfer of spectrum resources from participating primary spectrum holders (PSH's) to one or more alternate spectrum holders (ASH's); (2) Reclaiming spectrum resources from an ASH back to the corresponding PSH on request; (3) Initiating queries to PSH's based on requests from MMD's, or through other ASH's; and (4) Performing a series of predictive resource allocations that may optimize spectrum use as the MMD moves between a number of regions.

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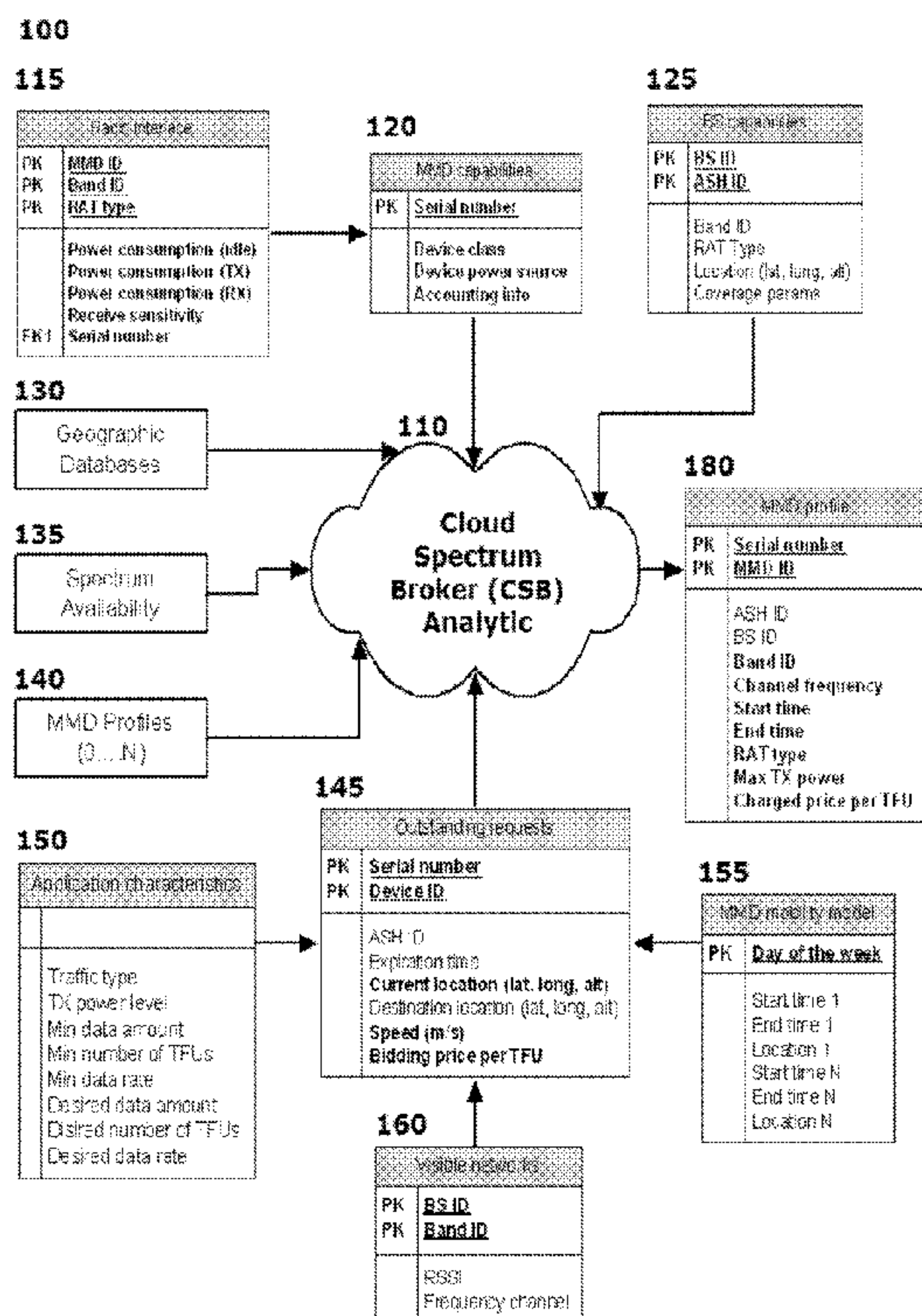


FIG. 1

(57) Abstract: A system and method are provided for implementing a spectrum management analytics (SMA) algorithm that references a plurality of enumerated inputs to generate a set of output parameters for use in attempting to optimize spectrum. The SMA algorithm is a part of a cloud spectrum broker (CSB) analytic. The CSB analytic provides for: (1) Managing CSS transactions involving transfer of spectrum resources from participating primary spectrum holders (PSH's) to one or more alternate spectrum holders (ASH's); (2) Reclaiming spectrum resources from an ASH back to the corresponding PSH on request; (3) Initiating queries to PSH's based on requests from MMD's, or through other ASH's; and (4) Performing a series of predictive resource allocations that may optimize spectrum use as the MMD moves between a number of regions.

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CLOUD BASED SPECTRUM MANAGEMENT ANALYTICS**BACKGROUND**

This application claims priority to U.S. Provisional Patent Application No. 61/603,261, entitled "Intelligent Spectrum Allocation Based on User Behavior Patterns For Efficient Spectrum Usage," filed on February 25, 2012. This application is related to co-pending International Patent Application Nos. (Attorney Docket Nos. P43616PCT and P43618PCT), filed on the same day as this application, the disclosures of which are hereby incorporated by reference herein in their entirety.

Field of the Disclosed Embodiments

This disclosure relates to systems and methods for implementing a spectrum management analytics (SMA) algorithm as part of an automated cloud spectrum broker (CSB) to provide spectrum management for networks using spectrum allocated through a Dynamic Spectrum Access (DSA) scheme that allows spectrum holders, or a proxy assigned to manage a given allocation of spectrum, to temporarily "rent" access to the spectrum they hold to other entities.

Related Art

The last decade and a half has witnessed an explosion in growth in the use of, and requirements for, wireless data communications, particularly by individual users operating, for example, through licensed mobile cellular network operators. This growth continues unabated today as the numbers and types of wireless devices employed by the individual users to access all manner of wireless networks via various communication paths continue to multiply, increasing demand for available spectrum. As the increase in demand for wireless data access continues, the world is headed toward a global spectrum shortage. There is a finite amount of spectrum that can be tapped to support wireless data communication. Availability of wireless spectrum for the increasing numbers and types of mobile devices is key to the continued use of the spectrum to exchange data and for economic growth.

An availability of ever increasingly-capable wireless data communications has also created in individual customers an expectation of a certain quality of service. In short, individual wireless data communication consumers expect quality wireless data communications to be available anytime and anyplace. If solutions are not found, users of wireless devices will frustratingly experience increased instances of dropped calls and slow data speeds all while paying higher fees for access to the scarce resource that will be the wireless data and voice communication spectrum.

Currently, wireless devices are used to provide individual customers virtually instantaneous and continuous wireless access to email, social media, applications and streaming video. These wireless devices are estimated to use 25 to 125 times the amount of spectrum that was used by earlier generation cellular telephones. Various industry estimates
5 expect growth in global mobile data traffic to double every 1-2 years for the foreseeable future.

Exclusive mobile spectrum licenses carve out to their licensees portions of the available spectrum that are used for wireless data and voice communication. Licensees in any geographic area include government agencies, which sometimes reserve communication spectrum to certain "required" wireless voice and data communications. A non-exhaustive list
10 of these communications users includes broadcast radio and television communications, satellite communications, public safety and emergency services communications, military communications, and certain other commercial communication requirements to include, for example, communications with aircraft for navigation and air traffic control. Licensees in particular geographic areas also include mobile cellular network operators. A cursory review
15 of the breakdown of the licensed spectrum for any particular geographic area reveals that the availability of new spectrum to support the assignment of additional exclusive licenses to any particular licensee is nearly exhausted.

A detailed review of the challenges faced by mobile cellular network operators starts with an overview of their operations. Mobile cellular network operators license spectrum
20 bands for their exclusive use within a particular geographic region. These entities then contract with individual customers to provide certain levels of service with express or implied guarantees of connectivity, and of communications fidelity at increasing rates of delivery. As mobile cellular network communication traffic continues its dramatic increase, congestion occurs today and the congestion problem is forecast to rise significantly in coming years in the
25 portions of the spectrum currently licensed to mobile cellular network operators to support wireless voice and data communications.

In the face of current and forecast issues regarding network congestion in their licensed spectrums, mobile cellular network operators have taken to purchasing additional exclusive spectrum licenses in the secondary market from other exclusive licensees (spectrum holders)
30 whose licensed spectrum is underused or otherwise available. Buying additional spectrum licenses allows mobile cellular network operators to build or expand their networks and handle more customer traffic. In fact, in late 2011, one major mobile cellular network operator in the United States reached an agreement, subject to regulatory approval, to buy a license for a small

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swath of wireless communication spectrum (around 20 MHz) from several broadcast cable companies for an amount that was reported to be in excess of three and one half billion dollars.

Efforts are ongoing to optimize wireless data communication to make more effective use of available spectrum. Consider the available spectrum as a pipe with a finite maximum diameter. Ongoing efforts attempt to optimize the flow of data through that pipe, thereby reducing the amount of spectrum used. These efforts include use of compression techniques, video optimization and burst transmissions such that overall data transmission through the pipe is streamlined and optimized, *i.e.*, techniques are implemented to pass larger amounts of data in what appears to be a smaller volume of flow through the pipe. Additional efforts are focused on concepts such as Wi-Fi offload or small cell development to ease the burden on the saturated portions of the spectrum exclusively licensed to mobile cellular network operators. All efforts at making data flow more efficient, thereby improving spectral efficiency, will reap benefits. Regardless of these efforts, however, the pipe will never get any bigger due to the fixed, finite spectrum covered by licenses. The above efforts may delay the inevitable. There will still come a time, however, when the currently licensed portions of the spectrum that support commercial mobile voice and data communications will become overburdened. When this overburdening occurs, a mobile cellular network operator has at its disposal methods, some of which are used today, by which to maintain service across its exclusively-licensed spectrum for all of its individual customers. Often these methods reduce the quality of service experienced by individual customers. Common techniques include, for example, mobile cellular network operators "throttling" rates at which data may be received by individual customers. Of course, as with any supply and demand scheme, a mobile cellular network operator can exact a premium from some percentage of its individual customers according to currently-licensed spectrum for its use to prioritize which of the individual customers get "throttled" last.

SUMMARY OF DISCLOSED EMBODIMENTS

A review of utilization of certain of the above-discussed licensed spectrums, other than those licensed to mobile cellular network operators, reveals that, although allocated to a specific entity for use at particularly scheduled times or on an as-needed basis, an overall rate of utilization of certain licensees spectrum may actually be very low. The spectrum that is allocated to certain services, other than commercial mobile wireless voice and data communication and Wi-Fi services, may experience actual overall average utilization rates as low as 1%. For example, some government entities only require high use of their spectrum in

times of emergency. Theoretically, across the wireless spectrum, up to an estimated 4 GHz of spectrum is underused.

One industry solution that has been suggested would be to allow individual wireless devices to conduct autonomous spectrum sensing to detect unused spectrum and to tap into that spectrum for individual wireless device use on an ad hoc basis. This "open market" or "opportunistic" method, which allows the individual customer to seek out and use the most effective and most economical service regardless of how that service is delivered to the individual customer's wireless device, is not according to the current paradigm. This method appears, according to current technology, to pose a level of chaos that will not solve the problem. Additionally, spectrum holders whose spectrum may be accessed require full control of their spectrum at times without interference from randomly encroaching wireless devices. The spectrum sensing solution would disrupt such control and introduce interference. There may come a time when such an open market method may be feasibly implemented. At that time, it will be appropriate to include within that open market method a version of the spectrum brokering scheme discussed below.

Some have suggested that the allocation of spectrum should implement utility models based on fairness, content type, and differences in providers. This suggested solution is largely discounted as it is postulated to create fragmentation and lead to inefficiencies that would only exacerbate the currently-forecast difficulties. Others have suggested using cognitive pilot channels (wireless spectrum) to advertise available unused or underused spectrum. This "solution," however, would require use of additional spectrum to implement the advertising and would be largely uncontrolled leading to increased chaos. Use of static databases to locate unused spectrum has also been proposed, but is not considered dynamic enough to manage the problem longer term. Spectrum required by individual users for any given period in any given location is dynamically changing, particularly when the users are mobile. This calls for requiring an equally dynamic automated solution by which to manage spectrum allocation. The problems of overcrowding in certain portions of the spectrum can be alleviated by executing a disciplined scheme to tap into the underused portions of the spectrum in a manner that meets the requirements of all of the respective licensees.

In contrast to the open market method described above is a controlled market method. The controlled market method is based on the mobile cellular network operator/individual customer model that is in place today. An individual customer does not generally access any spectrum except through the licensed spectrum controlled by the mobile cellular network operator that provides the service and equipment to the individual customer. It is in this model

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that the mobile cellular network operator provides a contracted-for level of service with certain guarantees and disclaimers, while exercising some modicum of control. For example, based on this relationship, the mobile cellular network operator can throttle an individual customer's access to wireless communications by slowing the rate at which those communications are
5 provided to the individual customer's wireless device. The mobile cellular network operator could also block data transmission from reaching the individual customer's wireless device. The mobile cellular network operator can also control what applications an individual customer may be able to access, and what applications the individual customer's wireless device may support. Because the controlled market method is the method generally in place today, the
10 balance of this disclosure will deal with implementation of the disclosed systems and methods in a controlled market. It should be recognized, however, that the systems and methods according to this disclosure may be equally enabled in an open market method if an open market method becomes the paradigm for supporting individual customers' wireless communication needs. Also, the term mobile cellular network operator is used to generically
15 refer to any commercial provider that exclusively licenses spectrum in support of providing wireless data and voice communications to a number of individual customers/users on a for-fee basis.

Based on the above shortfalls, a new paradigm is emerging for global spectrum optimization in a controlled environment. New to the wireless industry is a discussion of
20 temporary spectrum license rental/leasing as opposed to spectrum license sale via auction or secondary market transactions. Exclusive licensees of unused or underused spectrum may provide an amount of spectrum at a particular time, in a particular location, to the marketplace in which licensees that require additional spectrum may acquire temporary access to the offered spectrum for a fee or appropriate consideration. There is a worldwide push for
25 regulations that allow licensed spectrum holders to temporarily transfer, *e.g.* rent or lease, access to their unused or underused spectrum to other entities requiring spectrum such as mobile cellular network operators. This creates a win-win situation where the other licensees gain access to additional spectrum resources, which would not otherwise be available, while the spectrum holders with unused spectrum get a financial incentive or other consideration.
30 This may be particularly attractive to the large majority of licensed spectrum holders whose utilization is well less than 100%, but that are not able to relinquish the spectrum completely through sale or other transaction based on their need to keep the spectrum reserved to their own use in certain areas at certain times.

According to proposed schemes, multiple primary spectrum holders (PSH's) of underused spectrum may act as spectrum suppliers. Multiple alternate spectrum holders (ASH's), such as, for example, mobile cellular network operators, may seek to augment their own exclusively-licensed spectrum by renting spectrum from the spectrum suppliers as spectrum renters. The mobile cellular network operator needs to support its individual customers operating its individual wireless devices connected to the mobile cellular network. The mobile cellular network operator is in a best position to monitor the use of its network by its individual customers according to time and location. When the mobile cellular network operator determines that its licensed spectrum will not meet customer demand for a particular location at a particular time, *e.g.*, busiest periods of the day, the mobile cellular network operator, acting as an ASH, may execute a transaction such as, for example, placing a real-time bid for spectrum, to temporarily acquire additional spectrum in a particular location at a particular time that has been made available by a PSH in a controlled marketplace.

Prior to offering portions of its underused spectrum to the marketplace for access by potential ASH's, the PSH generally needs to be assured that it can regain control of its spectrum when a need arises. A clear mechanism to support such assurances is provided in the exemplary embodiments discussed in this disclosure. As discussed in this disclosure, DSA generally refers to a scheme that allows PSH's to temporarily rent their spectrum to ASH's on the condition that the rented spectrum can be relinquished to the PSH on demand. It is estimated that, through implementation of such a scheme across all spectrum to 6 GHz, as much as 75% of the underused 4 GHz of spectrum may be recovered for use by multiple ASH's. This complete recovery would require full implementation of the disclosed spectrum brokering scheme and full cooperation from all PSH's. Actual implementation may initially realize a recovery of spectrum at well less than 2 GHz as it is anticipated that certain PSH's may choose not to participate, and others may temper their participation, at least initially. To put the above numbers in some perspective, however, it should be realized that a 500 MHz recovery would effectively double the amount of spectrum currently available for mobile cellular network communications.

A challenge in achieving an efficient and scalable DSA scheme that becomes economically viable is effective spectrum management. In other words, given the temporary lease of spectrum to different operators or users, in different locations, for different time periods, a challenge resides in determining how best to coordinate the leasing of the spectrum so that the spectrum brokering scheme maximizes: (1) the incentive for the ASH's; (2) the incentive for the PSH's and (3) experience for the user/operator that is paying for that spectrum

(ideally, with minimal cost), all while avoiding interference and assuring the PSH that its spectrum is recoverable on demand. This is an optimization problem that lends itself to the use of computational analytics. Currently, there are no known global spectrum management schemes with computational analytics across networks employing DSA. While mobile cellular
5 network operators do make use of spectrum management within their own networks, there is no cross-network, or cross-operator, spectrum management between potential ASH's. Today, with spectrum exclusively licensed, there has been no push for a large scale spectrum management. However, with future spectrum exhaustion of their exclusively-licensed spectrum expected by carriers, the larger pool of rented spectrum provides a greater pool of
10 spectrum resources from which to optimize utilization, *i.e.*, optimization would no longer be limited to just the local spectrum resources of each individual carrier.

An overarching cloud spectrum services (CSS) approach to realize a form of DSA that is centered on the cloud is proposed in U.S. Provisional Patent Application No. 61/603,261. Specifically, the cloud is envisioned as the mechanism to enable management, in real-time or
15 in near real-time, of the dynamic allocation, reclaiming, de-allocation, auditing, and optimizing the use of spectrum that has been the subject of a transaction between PSH's and operators/users/content providers acting as ASH's.

U.S. Patent Application No. [Attorney Docket No. 064-0060] proposes a two-level spectrum management analytic optimization that effectively bifurcates spectrum optimization
20 requirements and responsibilities between a regional global spectrum broker and a series of local spectrum brokers acting under an umbrella of the regional global spectrum broker. The approach described in the [0060] Application proposes to keep from overburdening the regional global spectrum broker's, and the local spectrum brokers', computational capabilities by effectively managing individual optimization requirements between the global spectrum
25 broker and the local spectrum brokers. That application specifically discusses a concept of local and global optimization for spectrum management according to a specified brokering scheme. However, in order to perform the optimization described in the [0060] Application, it is appropriate to describe the inputs, the outputs and the guidelines of an algorithm used to resolve spectrum optimization at one or both of the global and local spectrum broker levels
30 described in the [0060] Application. It should be recognized that all of the inputs depicted and described below may not be available to one or the other of the global spectrum broker or the local spectrum brokers. Each of the proposed inputs, however, is appropriate to be employed at one or the other of the levels to generate appropriate output multi-mode device (MMD), or wireless device, profiles in support of the DSA.

Exemplary embodiments may provide a spectrum management analytics (SMA) algorithm that references a plurality of enumerated inputs to generate a set of output parameters for use in attempting to optimize spectrum through the DSA approach.

Exemplary embodiments may provide that the SMA algorithm is at least a part of a
5 cloud spectrum broker (CSB) analytic. Among other things, the CSB analytic, as described in the above-referenced applications, may be responsible for one or more the following functions: (1) Managing CSS transactions involving the transfer of spectrum resources from at least one participating PSH to one or more ASH's (for the purposes of the discussion in this disclosure, it must be recognized that the one or more ASH's may be, for example, a mobile cellular network
10 operator or other comparable entity operating in a controlled market method, or otherwise an MMD, or individual wireless device, in an open market or opportunistic method, as discussed above); (2) Reclaiming of spectrum resources from an ASH (including a mobile cellular network operator or MMD) back to the corresponding PSH upon request of the PSH for immediate release of its spectrum to its own use; (3) Initiating queries to PSH's based on
15 requests either directly received from MMD's or through other ASH's when acting in the controlled market method; and (4) Evaluating an MMD's mobility model and, based on the evaluated MMD's mobility model, performing a series of predictive resource allocations that may optimize spectrum use as the MMD moves between a number of regions. As an example of this last task, the CSB analytic may be able to predict a direction of movement of an MMD
20 between regions, or areas of coverage, and to provide upfront an established connectivity to the MMD, which, for example, may include setting up roaming resources in a predictive fashion.

In exemplary embodiments, the CSB analytic may include a distributed architecture. The CSB analytic may, for example, be implemented as an independent entity, or as part of an ASH or PSH. The CSB analytic may communicate with other CSB analytics for multiple
25 purposes in carrying out the above-described tasks, including spectrum availability negotiation. In other words, CSS transactions may involve communication amongst multiple CSB's.

In exemplary embodiments, an SMA algorithm, implemented as a computing engine at the CSB may take, as inputs, a set of parameters and generate an output that includes some number of MMD profiles. Information provided as inputs to the CSB analytics is obtained
30 from various components of the CSS architecture referenced above.

In exemplary embodiments, an MMD profile may be generated as an output of the CSB analytic. Such a generated MMD profile may specify a resulting set of operating parameters for one or more individual MMD's after the CSB computation. The one or more individual

MMD's receiving an updated MMD profile may then adopt the operating parameters as specified in the updated MMD profile.

In exemplary embodiments, as a part of the output of the CSB analytics, the CSB may also perform any of the following functions: (1) Notifying a cloud spectrum database (CSD) that a portion of a spectrum availability has been allocated, identifying the ASH to which the portion of the spectrum availability has been allocated; (2) Notifying the CSD that a portion of the spectrum availability that was previously allocated has been de-allocated and returned to the PSH at the request of the PSH or according to pre-negotiated conditions with the PSH; (3) Negotiate with a PSH for an asking price (cost, lowest bid or other consideration) of an existing spectrum availability or inquire about new spectrum availabilities that are not present in the CSD, with any conditions that the PSH may apply to the new spectrum availabilities; and (4) Negotiate with an ASH (mobile cellular network operator, other entity or MMD) the bidding price or other consideration offered for a spectrum availability and also particular application characteristics that may be supported by the transaction. It should be understood that for functions (3) and/or (4) described above, the CSB may enter the discussion with its own pricing model in addition to, or in lieu of, the pricing models proposed by the ASH and/ or PSH.

In exemplary embodiments, in the controlled market method described above, the mobile cellular network operator or other controlling entity may receive the MMD profiles output by the CSB and direct operations of the MMD's employed by its users/customers in accordance with the received MMD profiles.

The allocation of the temporary resource will be highly localized and require that the allocated temporary resource can be returned to the control of the PSH according the terms of the above-discussed agreement regarding the PSH's individual preemptive and/or prioritized needs for that resource.

These and other features, and advantages, of the disclosed systems and methods are described in, or apparent from, the following detailed description of various exemplary embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

Various exemplary embodiments of the disclosed systems and methods for implementing a spectrum management analytics (SMA) algorithm as part of an automated cloud spectrum broker (CSB) to provide spectrum management for networks using spectrum allocated through a Dynamic Spectrum Access (DSA) scheme that allows spectrum holders, or a proxy assigned to manage a given allocation of spectrum, to temporarily "rent" access to the

spectrum they hold to other entities will be described, in detail, with reference to the following drawings, in which:

FIG. 1 illustrates an overview of an input and output scheme for an exemplary SMA algorithm as part of an automated CSB analytic to provide spectrum management for networks using spectrum allocated through a DSA scheme according to this disclosure;

FIG. 2 illustrates a block diagram of an exemplary computation engine for an automated CSB analytic to implement the SMA algorithm for spectrum management according to this disclosure; and

FIG. 3 illustrates a flowchart of an exemplary method for implementing the SMA algorithm for spectrum management via an automated CSB analytic according to this disclosure.

DETAILED DESCRIPTION OF THE DISCLOSED EMBODIMENTS

The systems and methods for implementing a spectrum management analytics (SMA) algorithm as part of an automated cloud spectrum broker (CSB) to provide spectrum management for networks using spectrum allocated through a Dynamic Spectrum Access (DSA) scheme that allows spectrum holders, or a proxy assigned to manage a given allocation of spectrum, to temporarily "rent" access to the spectrum they hold to other entities will generally refer to this specific utility for those systems and methods. Exemplary embodiments described and depicted in this disclosure should not be interpreted as being specifically limited to any particular analytics approach, to any particular analytics algorithm, to making use of any particular program for implementing the analytics approach, or to any specific system infrastructure for a particular network, or for an individual MMD for use within that network, or for use autonomously.

While specific reference is made throughout this disclosure to application of the disclosed systems and methods to a conventionally understood "controlled market" method for providing wireless communication services, it should be understood that the systems and methods according to this disclosure are not limited to the conventionally understood "controlled market" method. The systems and methods according to this disclosure may be equally applicable to any method for providing wireless communication service through direct interaction with individual MMD's. The discussion references application to the "controlled market" method only for familiarity and ease of understanding of the proposed implementation.

Specific reference to, for example, any particular MMD, wireless device or mobile cellular network configuration should be understood as being exemplary only, and not limited,

in any manner, to any particular class of MMD's or other wireless devices used in any particular configuration of a wireless network, whether fixed or mobile.

Individual features and advantages of the disclosed systems and methods will be set forth in the description that follows, and will be, in part, obvious from the description, or may
5 be learned by practice of the features described in this disclosure. The features and advantages of the systems and methods according to this disclosure may be realized and obtained by means of the individual elements, and combinations of those elements, as particularly pointed out in the appended claims. While specific implementations are discussed, it should be understood that this is done for illustration purposes only. A person skilled in the relevant art
10 will recognize that other components and configurations may be used without departing from the spirit and scope of the subject matter of this disclosure.

Review of spectrum use indicates that there are a large number of inputs that may be considered in optimizing the spectrum utilization. For example, there are certain peak times when, for example, mobile cellular networks are saturated and other times when the traffic is
15 less dense. This traffic saturation may be geographically diverse. This applies not only to mobile cellular network operations, but also applies to other portions of the wireless communication spectrum. Consider, for example, differences in levels of military traffic within their spectrum bands around, for example, the large naval bases in San Diego, California and Norfolk, Virginia, and the significantly less dense traffic on military wireless
20 channels that may be experienced, for example, in some portions of the Midwest. So there are numerous dimensions to the spectrum analysis and utilization problem for both PSH's and potential ASH's. There is a location or geographic dimension to the problem that is only made more complex based on the mobility of a particular device including "roaming" across several regions. There is also a time dimension. Back to the utilization in the vicinity of San Diego
25 and Norfolk, peak utilization may occur generally between 8 AM and 4 PM local time on weekdays, while utilization outside those times may be significantly less. Further, there is a frequency aspect to the spectrum analysis and use problem. Certain frequency bands are implemented with equipment providing less capability for particular users, compared to mobile cellular networks implemented according to today's more capable technologies and standards.
30 Thus, the frequency bands that may be most advantageously accessed are those that could be judged on the basis of providing the best capability for the ASH, *e.g.*, mobile cellular network operators, and the frequency bands need to be non-interfering between competing ASH's in a particular region that may employ spectrum at particular frequencies. As such, any algorithm that constitutes an optimization scheme for spectrum use must address at least these three

dimensions. Each of time, space and frequency utilization may need to be dynamically optimized.

A cloud based spectrum marketplace is proposed. PSH's whose spectrum is underused or otherwise can be made available may employ the marketplace to dynamically barter or
5 auction their spectrum availability. With implementation of such a marketplace, PSH's who know how often, how much, and generally at what times, they employ the spectrum exclusively licensed to them, may populate a database to indicate periods when their spectrum is unused, or underused, in order that potential ASH's as entities that require or desire additional spectrum services, perhaps at specific times in specific locations, may enter into a
10 transaction based on the listed periods of spectrum availability provided to the marketplace by one or more PSH's in order to maintain a particular quality of experience for the ASH's users even during times of peak utilization.

The availability of the spectrum under the proposed marketplace scheme will often be subject to the PSH's ability to reclaim that spectrum on-demand. This capacity is part of the
15 system that implements the disclosed marketplace scheme. This requirement may also drive the amount of a fee, or other consideration, that the ASH may be willing to offer for the spectrum availability. If, for example, it is more unlikely than likely that the spectrum will need to be reclaimed immediately in, for example, a peak period for operations by the ASH, that spectrum may garner higher bids than spectrum that may be immediately recallable and is
20 likely to be recalled on some routine basis during those periods of peak operations.

The marketplace may be available to oversee transactions regarding available spectrum according to a mechanism that can also inform at least the PSH regarding what entity or entities are "renting" its spectrum at any particular point in time. This may be appropriate so that the PSH can indicate to a renting ASH a requirement to recover the spectrum to the PSH's
25 use.

FIG. 1 illustrates an overview 100 of an input and output scheme for an exemplary SMA algorithm as part of an automated CSB analytic to provide spectrum management for networks using spectrum allocated through a DSA scheme according to this disclosure. As shown in FIG. 1, a central component of the systems and methods according to this disclosure
30 may be a CSB analytic 110.

Myriad sources of information are provided to be referenced as inputs to the CSB analytic 110 in order that the CSB analytic may output a specific MMD profile 180 to be used by a specific MMD of a specific user according to the results of an SMA algorithm optimizing

those inputs and theoretically providing an operable profile for the specific MMD given consideration of all the relevant inputs.

The multiple and varied sources of information generally provide information regarding the following: a radio interface 115, MMD capabilities 120, base station capabilities 125,
5 information from geographic databases 130, information from a spectrum availability database 135 (such as a CSD), information from an MMD profile database 140, and information regarding outstanding requests 145, which may represent a compilation of application characteristics 150, MMD mobility models 155, and information on visible networks 160.

As is indicated at the top of FIG. 1, information is intended to be received not only
10 from individual users regarding, for example, MMD capabilities 120, but base station capabilities 125 that may affect an output MMD profile 180. For example, consider the situation where a user device may support a certain level of capability, but a base station by which the user device communicates with the spectrum in a given location has not been upgraded to support that level of capability, that information is appropriate to be considered by
15 the CSB analytic 110. There is, for example, no point in assigning a specific frequency band of spectrum via a particular base station that the base station cannot support.

It should be understood that, with regard to several sources of information shown in FIG. 1, the information provided may remain reasonably static over a particular timeframe. With regard to other of the sources of information shown in FIG. 1, however, the information
20 provided may be dynamically changing in near real-time. As such, there is a time dimension to the CSB analytic 110 that must be taken into consideration. For example, information regarding the radio interface 115, the MMD capabilities 120, and the base station capabilities 125, as well as information recovered from the geographic databases 130, may remain fairly static over time. With regard to the geographic databases, for example, new roads and/or
25 railroads are not being built every day; likewise with regard to the base station capabilities 125, these capabilities are not being upgraded on an immediate basis. Other information, however, particularly that information dealing with the outstanding requests 145, changes very dynamically. This information changes the dynamics of the optimization that may be undertaken by the CSB analytic 110 on a dynamic basis. It is for this reason, among others,
30 that the CSB analytic may be fully automated to account for dynamically changing conditions regarding any of the many inputs on a real-time or near real-time basis.

Each of the information sources 115-160 shown in FIG. 1, with the information depicted associated information elements, may provide relevant static and dynamically changing inputs to be acted upon by the CSB analytic 110 as the CSB analytic 110 executes an

SMA algorithm to provide outputs of MMD profiles 180. The output MMD profiles 180 may be sent directly to individual MMD's, or may be provided through one or more ASH's to individual MMD's in order that the individual MMD's are caused to operate most efficiently within the available spectrum.

5 FIG. 2 illustrates a block diagram of an exemplary computation engine 200 for an automated CSB analytic to implement the SMA algorithm for spectrum management according to this disclosure.

The exemplary computation engine 200 may include a user interface 210 by which an individual or entity tasked with monitoring, overseeing or implementing the execution of the
10 CSB analytic may make manual inputs to the exemplary computation engine 200, and may otherwise communicate information via the exemplary computation engine 200 as, for example, outputs to an ASH or MMD. The user interface 210 may be configured as one or more conventional mechanisms that permit an individual or entity to input information to the exemplary computation engine 200. The user interface 210 may include, for example, such
15 mechanisms as a keyboard and/or mouse, or a touchscreen with "soft" buttons for communicating commands and information to the exemplary computation engine 200. The user interface 210 may alternatively include a microphone by which an individual or entity may provide oral commands to the exemplary computation engine 200 to be "translated" by a voice recognition program or otherwise. The user interface 210 may otherwise comprise
20 simply a data port by which compilations of data to be input to the exemplary computation engine 200 may be read from transportable digital media. In such a scenario, data used for operation of the exemplary computation engine 200 may be compiled at, for example, separate user workstations and provided to the exemplary computation engine 200 by physically, or otherwise, transferring the digital data media from the workstation at which the information is
25 recorded to the exemplary computation engine 200 to be read by a compatible digital data media reader acting as a user interface 210 in the exemplary computation engine 200.

The significant amounts of information appropriate to executing the CSB analytic in the exemplary computation engine 200 will not be input via a manual user interface 210. Rather, it is anticipated that information from a plurality of information sources such as those shown in
30 FIG. 1 will be automatically received by the exemplary computation engine 200 through other channels. This level of automation and data exchange is appropriate to ensure that the exemplary computation engine 200 executes the CSB analytic in real time, or near real-time, in order to keep pace with the dynamically changing requirements provided by certain of the information sources.

The exemplary computation engine 200 may include one or more local processors 220 for individually undertaking the processing and control functions that are carried out by the exemplary computation engine 200. Processor(s) 220 may include at least one conventional processor or microprocessor that interprets and executes instructions and processes outgoing
5 and incoming control information and data via the different input and output channels for exchange of such information in the exemplary computation engine 200.

The exemplary computation engine 200 may include one or more data storage devices 230. Such data storage device(s) 230, which may include hard disk storage as well as solid-state devices, may be used to store data, and operating programs or applications to be used by
10 the exemplary computation engine 200, and specifically by the processor(s) 220. Data storage device(s) 230 may include a random access memory (RAM) or another type of dynamic storage device that stores information and instructions for execution by the processor(s) 220. Data storage device(s) 230 may also include a read-only memory (ROM), which may include a conventional ROM device or another type of static storage device that stores static information
15 and instructions for execution by the processor(s) 220. The data storage device(s) 230 may be those that are integral to the exemplary computation engine 200, or otherwise may be remotely located from, and accessible to, the exemplary computation engine 200.

The exemplary computation engine 200 may include at least one display device 240 by which the individual or entity tasked with monitoring, overseeing, or implementing the CSB
20 analytic may monitor a status of operation of the exemplary computation engine 200 to include, for example, the receipt of information from the multiple information sources appropriate to execution of the CSB analytic by the exemplary computation engine 200. The display device 240 may also be employed to monitor, for example, status of output MMD profiles provided to individual recipients. The display device 240 may be configured as one or
25 more conventional mechanisms that display information to individuals or entities interacting with the exemplary computation engine 200 for operation of the exemplary computation engine 200, or otherwise for displaying information such as that discussed above.

The exemplary computation engine 200 may include an external inputs reception device 250. The external inputs reception device 250 may incorporate a plurality of individual
30 information exchange interfaces by which the exemplary computation engine 200 communicates with at least some of the individual information sources shown, for example, in FIG. 1. Individual information elements may be received via individual paths, or may be consolidated along fewer paths than there are individual information sources, as depicted. For example, information radio interfaces and MMD capabilities may be received directly from

one or more MMD's. This information may be otherwise received via one or more ASH's. Information on base station capabilities is likely to be received from a particular ASH.

Depending on an involvement of an ASH in the communication chain between individual MMD's and the exemplary computation engine 200, information regarding outstanding

5 requests may be received from one or the other of individual MMD's or individual ASH's.

These communications interactions, it is anticipated, may occur via one or more of a plurality of individual information exchange interfaces that constitute the external inputs reception

device 250. Information from geographic databases and spectrum availability databases, as well as information regarding input MMD profiles may be received via the external inputs

10 reception device 250. Otherwise, a geographic database, for example, may be stored in one or more the data storage devices 230 associated with the exemplary computation engine 200. As will be described briefly below, information on spectrum availability and input MMD profiles may constitute portions of a stored cloud spectrum database (CSD) to be, therefore, readily accessible to the CSB analytic carried out by the exemplary computation engine 200.

15 The exemplary computation engine 200 may include a separate CSB analytic execution device 260. The CSB analytic execution device 260 may operate autonomously, or in combination with the processor 220 and/or one or more the data storage devices 230, to execute the SMA algorithm taking as inputs some or all of the plurality of inputs discussed above and providing as outputs individual MMD profiles according to the execution of the

20 SMA algorithm. The CSB analytic execution device 260 may, therefore, provide a mechanism by which to update, in a near continuous manner, a spectrum management scheme by providing updated MMD profiles directly to MMD's, or via ASH's, to attempt to facilitate optimum spectrum used for a particular region. Depending on an amount of computing overhead, potentially according to a two level analytic scheme such as that described in the

25 above-discussed [0060] Application, the CSB analytic execution device 260, as an element of the exemplary computation engine 200, may operate according to an update rate with intervals of less than 100 ms in order to remain responsive to the dynamic nature of the information being provided to the exemplary computation engine 200.

The exemplary computation engine 200 may include a cloud spectrum database (CSD)

30 270. As indicated above, the CSD 270 may provide to the exemplary computation engine 200, and specifically the CSB analytic execution device 260, information on current spectrum availability, and input MMD profiles for use by the exemplary computation engine 200 in executing the SMA algorithm.

The exemplary computation engine 200 may include an MMD profile output device 280. As indicated above, an output of execution of the CSB analytic is a plurality of MMD profiles to be communicated to, and accepted by, individual MMD's. The MMD profile output device 280 may be used to communicate the output MMD profiles directly to individual
5 MMD's, or via individual ASH's to one or more MMD's, which are overseen by, or otherwise in communication with, an individual ASH.

All of the various components of the exemplary computation engine 200, as depicted in FIG. 2, may be connected by one or more data/control busses 290. The data/control bus(es) 290 may provide internal wired or wireless communication between the various components of
10 the exemplary computation engine 200, as all of those components are housed integrally in the exemplary computation engine 200. Otherwise, in a preferred embodiment, the data/control bus(es) 290 will provide wireless communication to cloud components including at least the CSB analytic execution device 260 and the CSD 270. Based on the cloud-based nature of the system architecture, it should be understood that all or some of the components may be
15 remotely located with respect to each other as actual or virtual logical components of a system represented by the depicted exemplary computation engine 200.

It is anticipated that the various disclosed elements of the exemplary computation engine 200 may be arranged in combinations of sub-systems as individual components or combinations of components, integral to a single unit or remotely dispersed as a plurality of
20 elements or sub-units comprising the exemplary computation engine 200.

The exemplary embodiments may include a method for implementing the SMA algorithm for spectrum management via an automated CSB analytic. FIG. 3 illustrates such an exemplary method. As shown in FIG. 3, operation of the method commences at Step S3000 and proceeds to Step S3100.

25 In Step S3100, first information for executing a spectrum management analytics (SMA) algorithm using a cloud spectrum broker (CSB) analytic may be obtained. The first information is information that may remain relatively static over time. With reference to FIG. 1, information regarding radio interfaces, MMD device capabilities and base station capabilities, as well as information obtained from geographic databases, may be considered to
30 fall under this category of first information, which remains relatively static. Operation of the method proceeds to Step S3200.

In Step S3200, second information for executing the SMA algorithm using the CSB analytic may be obtained. The second information is information that may dynamically change at a very rapid rate in real-time. With reference again to FIG. 1, information regarding current

MMD profiles, spectrum availability and outstanding spectrum requests may be considered to fall under this category of second information, an update rate of which, as the information dynamically changes, may establish a refresh rate for the execution of the SMA algorithm to keep the output MMD profiles appropriately updated for spectrum optimization. Operation of
5 the method proceeds to Step S3300.

In Step S3300, the CSB analytic may negotiate with PSH's regarding additional spectrum availability to populate, for example, a cloud spectrum database. Operation of the method proceeds to Step S3400.

In Step S3400, the CSB analytic may negotiate with the PSH's regarding an asking
10 price, as a fee or other consideration, for existing spectrum availability to be offered to ASH's or MMD's. Operation of the method proceeds to Step S3500.

In Step S3500, the CSB analytic may negotiate with ASH's or MMD's regarding a bidding price, as a fee or other consideration, that the ASH or MMD is willing to offer/pay for requested spectrum availability. The CSB analytic may additionally negotiate with a particular
15 ASH or MMD regarding any application characteristics to be supported by the requested spectrum availability. Operation of the method proceeds to Step S3600.

In Step S3600, based on the obtained information, and any results of the above negotiations, the CSB analytic may execute the SMA algorithm to determine optimum output MMD profiles. Operation of the method proceeds to Step S3700.

20 In Step S3700, the determined optimum output MMD profiles may be communicated to a plurality of MMD's directly, or via one or more ASH's for implementation by the individual MMD's. Operation of the method proceeds to Step S3800.

In Step S3800, the CSB analytic may communicate to one or more cloud spectrum databases a change in status, *e.g.*, allocated or de-allocated, of a portion of the spectrum
25 availability. Operation of the method proceeds to Step S3900, where operation of the method ceases.

The disclosed embodiments may include a non-transitory computer-readable medium storing instructions which, when executed by a processor or multiple processors, may cause the processor or multiple processors to execute all or some of the steps of a method as outlined
30 above.

The above-described exemplary systems and methods reference certain conventional terms and components to provide a brief, general description of a suitable communication and processing environment in which the subject matter of this disclosure may be implemented for familiarity and ease of understanding. Although not required, embodiments of the systems and

methods according to this disclosure may be provided, at least in part, in a form of hardware circuits, firmware or software computer-executable instructions to carry out the specific functions described, including program modules, being executed by a processor or processors. It should also be understood that certain of the functions described above may be carried out by
5 virtual logical elements that may be cloud-based. Generally, program modules include routine programs, objects, components, data structures, and the like that perform particular tasks or implement particular data types.

Those skilled in the art will appreciate that other embodiments of the disclosed subject matter may be practiced with many types of communication equipment and computing system
10 configurations.

Embodiments may be practiced in distributed network and/or cloud-based communication environments where tasks are performed by local and remote processing devices that are linked to each other by hardwired links, wireless links, or a combination of both through a communication network. In a distributed network environment, program
15 modules may be located in local, remote and virtual logical cloud-based data storage devices.

Embodiments within the scope of this disclosure may also include non-transitory computer-readable media having stored computer-executable instructions or data structures that can be accessed, read and executed by processors using a compatible physical data reader, or executing an appropriate data reading scheme. Such computer-readable media can be any
20 available media that can be accessed by a processor or processors. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM, DVD-ROM, flash drives, thumb drives, data memory cards or other analog or digital data storage devices that can be used to carry or store desired program elements or steps in the form of accessible computer-executable instructions or data structures. Combinations of the above
25 should also be included within the scope of the computer-readable media for the purposes of this disclosure.

The exemplary depicted sequence of executable instructions, or associated data structures for executing those instructions, represents one example of a corresponding sequence of acts for implementing the functions described in the method. The steps of the method, as
30 depicted and described, are not intended to imply any particular order to the depicted steps, except as may be necessarily inferred when one of the depicted steps is a necessary precedential condition to accomplishing another of the depicted steps. Many of the operations and functions described may occur in parallel.

Although the above description may contain specific details, they should not be construed as limiting the claims in any way. Other configurations of the described embodiments of the disclosed systems and methods are part of the scope of this disclosure. This enables each user to use the benefits of the disclosure even if any one of the large number
5 of possible applications, for example, any particular MMD, do not need a specific aspect of the functionality described and depicted in this disclosure. In other words, there may be multiple instances of the components, particularly individual MMD's, each processing the content in various possible ways. It does not necessarily need to be one system used by all end users. Accordingly, the appended claims and their legal equivalents should only define the disclosure,
10 rather than any specific examples given.

CLAIMS

We claim:

1. A method for implementing dynamic spectrum access, comprising:
obtaining, by a processor, a first plurality of information inputs related to spectrum
5 usage in a particular geographic region, the first plurality of information inputs being based on
information that is generally static in nature over a specified time interval;
obtaining, by the processor, a second plurality of information inputs related to the
spectrum usage in the particular geographic region, the second plurality of information inputs
being based on information that is dynamically changing over the specified time interval;
10 executing, by the processor, a spectrum management optimization algorithm based on
the first plurality of information inputs and the second plurality of information inputs; and
outputting information on an updated characteristic profile to be adopted by a wireless
multi-mode device based on the execution of the spectrum management optimization
algorithm.
- 15 2. The method of claim 1, the first information comprising information on at least
one of radio interfaces, multi-mode device capabilities, base station capabilities and geographic
characteristics.
3. The method of claim 1, the second information comprising information on at least
one of multi-mode device input profiles and outstanding requests for access to additional
20 spectrum generated by a multi-mode device or an alternate spectrum holder.
4. The method of claim 3, the outstanding requests for access to additional spectrum
including at least one of an amount of monetary compensation or other consideration that the
multi-mode device or alternate spectrum holder offers for the access to additional spectrum.
5. The method of claim 4, the outstanding requests for access to additional spectrum
25 including an indication of any application, or requirements of an application, that the multi-
mode device or alternate spectrum holder requests be supported by the access to additional
spectrum.
6. The method of claim 5, the outstanding requests for access to additional spectrum
being based, at least in part, on a mobility model for a multi-mode device causing negotiation
30 between the processor for the particular geographic region and another processor for another
particular geographic region.
7. The method of claim 1, further comprising negotiating with a primary spectrum
holder regarding an availability of additional spectrum offered for transaction.

8. The method of claim 7, the negotiating including requesting of the primary spectrum holder an amount of monetary compensation or other consideration that the primary spectrum holder will accept for access to additional spectrum.

9. The method of claim 1, further comprising updating a stored database tracking
5 spectrum availability to indicate a status of offered additional spectrum in the particular geographic region as a result of a transaction to allocate access to additional spectrum to one of a multi-mode device and an alternate spectrum holder.

10. The method of claim 9, at least one of the processor and the stored database being cloud based.

10 11. The method of claim 1, the outputting of the information on the updated characteristic profile to be adopted by the multi-mode device being based on a transaction for access to additional spectrum through the execution of the spectrum management optimization algorithm.

12. A system for implementing dynamic spectrum access, comprising:
15 a first data exchange interface via which information inputs are received, the information inputs comprising a first plurality of information inputs related to spectrum usage in a particular geographic region, the first plurality of information inputs being based on information that is generally static in nature over a specified time interval and a second plurality of information inputs related to the spectrum usage in the particular geographic
20 region, the second plurality of information inputs being based on information that is dynamically changing over the specified time interval;

a spectrum management optimization algorithm execution device that optimizes available spectrum use in the particular geographic region based on the first plurality of information inputs and the second plurality of information inputs to determine optimum
25 profiles to be forwarded to and accepted by a plurality of wireless multi-mode devices; and

a second data exchange interface by which the system communicates the optimum profiles to be adopted by the plurality of multi-mode device based on the optimizing.

13. The system of claim 12, the first information comprising information on at least one of radio interfaces, multi-mode device capabilities, base station capabilities and geographic
30 characteristics.

14. The system of claim 12, the second information comprising information on at least one of multi-mode device input profiles and outstanding requests for access to additional spectrum generated by a multi-mode device or an alternate spectrum holder.

15. The system of claim 14, the outstanding requests for access to additional spectrum including at least one of an amount of monetary compensation or other consideration that the multi-mode device or alternate spectrum holder offers for the access to additional spectrum.

5 16. The system of claim 15, the outstanding requests for access to additional spectrum including an indication of any application, or requirements of an application, that the multi-mode device or alternate spectrum holder requests be supported by the access to additional spectrum.

10 17. The system of claim 16, the outstanding requests for access to additional spectrum being based, at least in part, on a mobility model for a multi-mode device causing negotiation between the processor for the particular geographic region and another processor for another particular geographic region.

15 18. The system of claim 12, the spectrum management optimization algorithm execution device optimizing the available spectrum use in the particular geographic region by negotiating with a primary spectrum holder regarding an availability of additional spectrum offered for transaction.

19. The system of claim 18, the negotiating including requesting of the primary spectrum holder an amount of monetary compensation or other consideration that the primary spectrum holder will accept for access to additional spectrum.

20 20. The system of claim 12, the spectrum management optimization algorithm execution device updating a stored database tracking spectrum availability to indicate a status of offered additional spectrum in the particular geographic region as a result of a transaction to allocate access to additional spectrum to one of a multi-mode device and an alternate spectrum holder.

25 21. The system of claim 20, at least one of the spectrum management optimization algorithm execution device and the stored database being cloud based.

22. The system of claim 12, the optimum profiles to be adopted by the plurality of multi-mode device based on the optimizing including a plurality of elements, the plurality of elements including more than one of an alternate spectrum holder identification, base station identification, spectrum band identification, a channel frequency, a start time for additional spectrum access, an end time for the additional spectrum access, a radio access technology (RAT), a maximum transmit power and a charged price for the additional spectrum access.

30

23. A non-transitory computer-readable medium storing computer-readable instructions which, when executed by a processor, causes the processor to execute a method for implementing dynamic spectrum access, the method comprising:

5 obtaining a first plurality of information inputs related to spectrum usage in a particular geographic region, the first plurality of information inputs being based on information that is generally static in nature over a specified time interval;

obtaining a second plurality of information inputs related to the spectrum usage in the particular geographic region, the second plurality of information inputs being based on information that is dynamically changing over the specified time interval;

10 executing a spectrum management optimization algorithm based on the first plurality of information inputs and the second plurality of information inputs; and

outputting information on an updated characteristic profile to be adopted by a wireless multi-mode device based on the execution of the spectrum management optimization algorithm.

15

1/3

100

115

Radio interface	
PK	<u>MMD ID</u>
PK	<u>Band ID</u>
PK	<u>RAT type</u>
	Power consumption (idle)
	Power consumption (TX)
	Power consumption (RX)
	Receive sensitivity
FK1	Serial number

120

MMD capabilities	
PK	<u>Serial number</u>
	Device class
	Device power source
	Accounting info

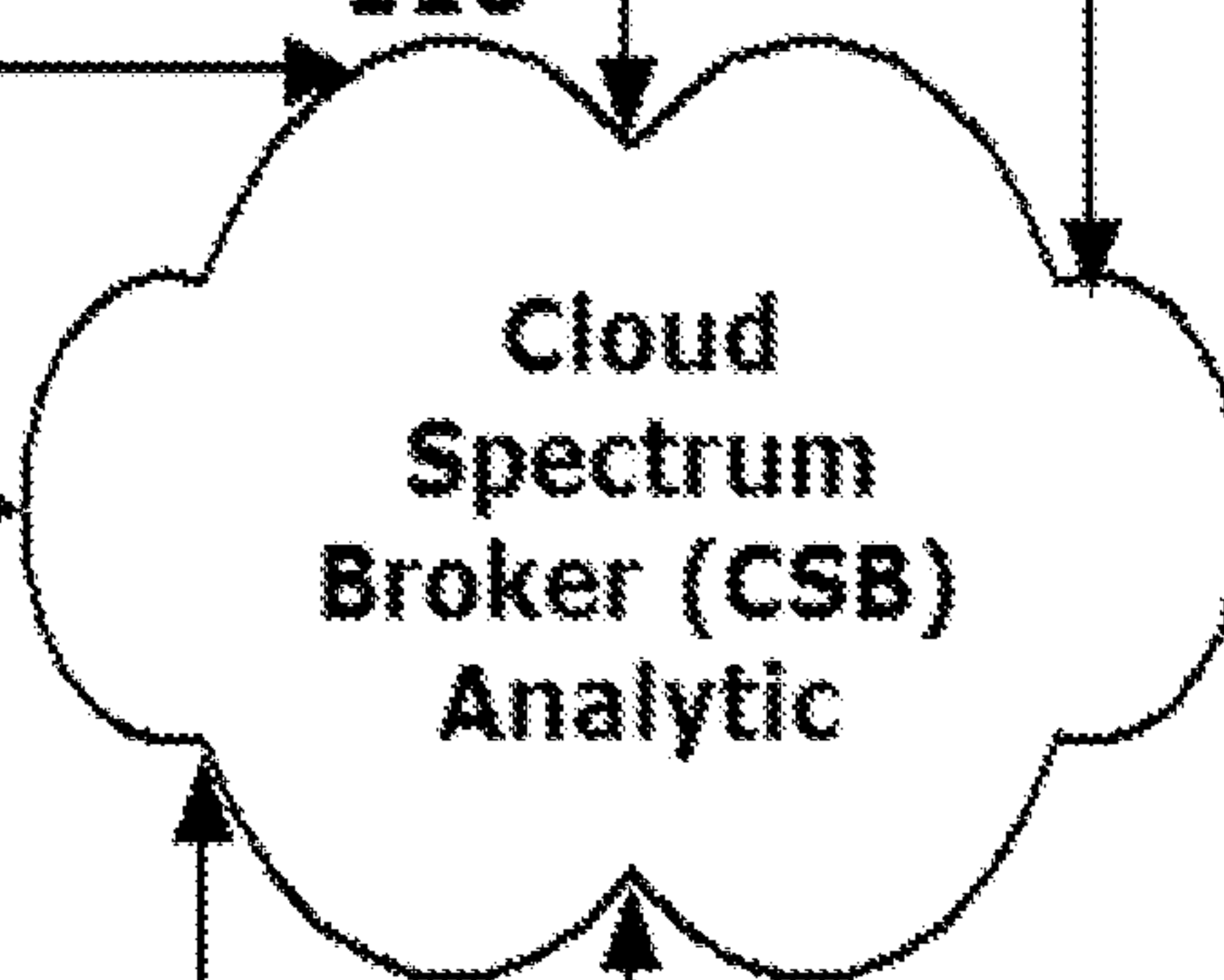
125

BS capabilities	
PK	<u>BS ID</u>
PK	<u>ASH ID</u>
	Band ID
	RAT Type
	Location (lat, long, alt)
	Coverage params

130

Geographic Databases

110



135

Spectrum Availability

140

MMD Profiles (0...N)

180

MMD profile	
PK	<u>Serial number</u>
PK	<u>MMD ID</u>
	ASH ID
	BS ID
	Band ID
	Channel frequency
	Start time
	End time
	RAT type
	Max TX power
	Charged price per TFU

145

Outstanding requests	
PK	<u>Serial number</u>
PK	<u>Device ID</u>
	ASH ID
	Expiration time
	Current location (lat, long, alt)
	Destination location (lat, long, alt)
	Speed (m/s)
	Bidding price per TFU

150

Application characteristics	
	Traffic type
	TX power level
	Min data amount
	Min number of TFUs
	Min data rate
	Desired data amount
	Desired number of TFUs
	Desired data rate

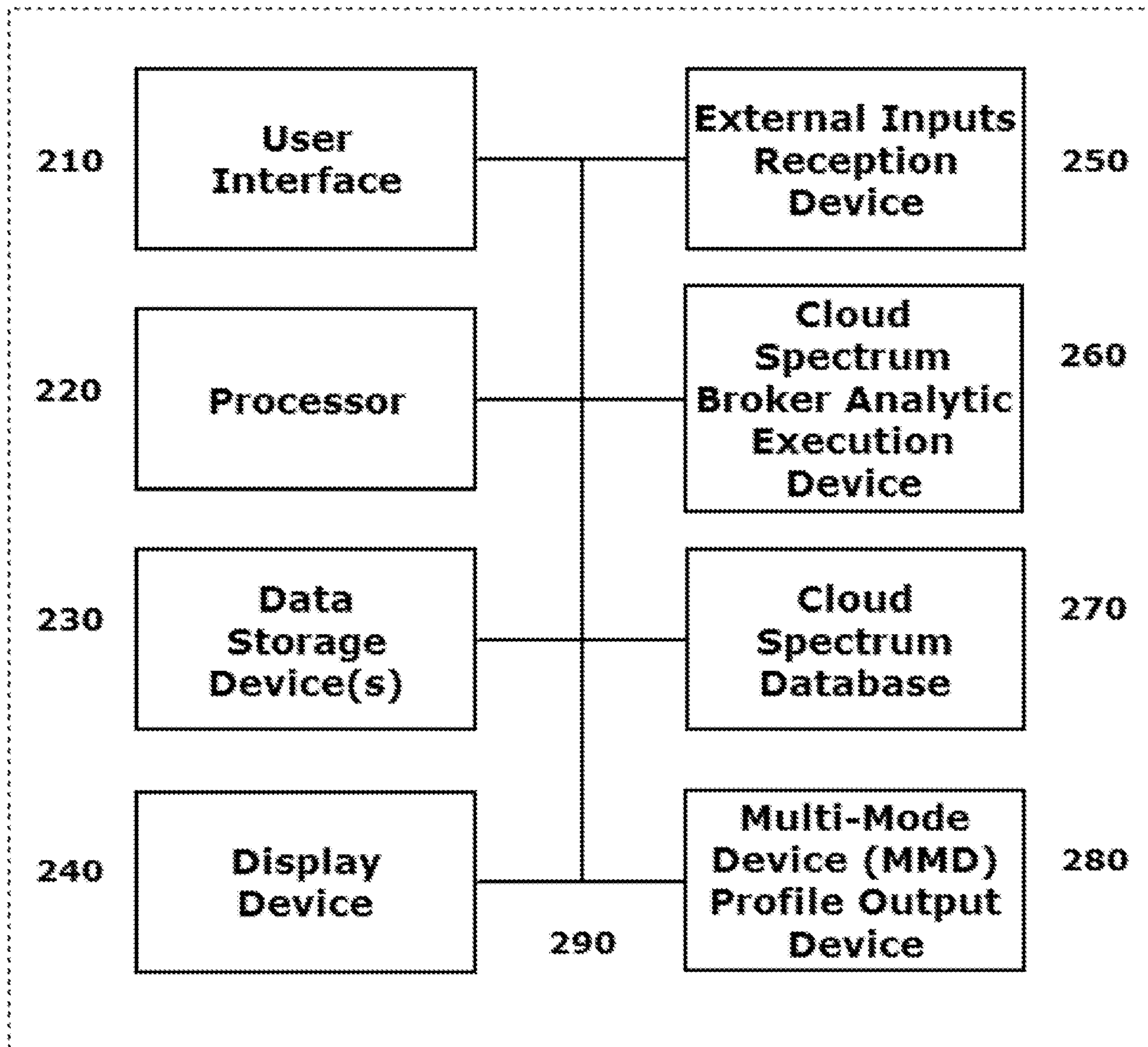
155

MMD mobility model	
PK	<u>Day of the week</u>
	Start time 1
	End time 1
	Location 1
	Start time N
	End time N
	Location N

160

Visible networks	
PK	<u>BS ID</u>
PK	<u>Band ID</u>
	RSSI
	Frequency channel

FIG. 1

2/3**200****FIG. 2**

3/3

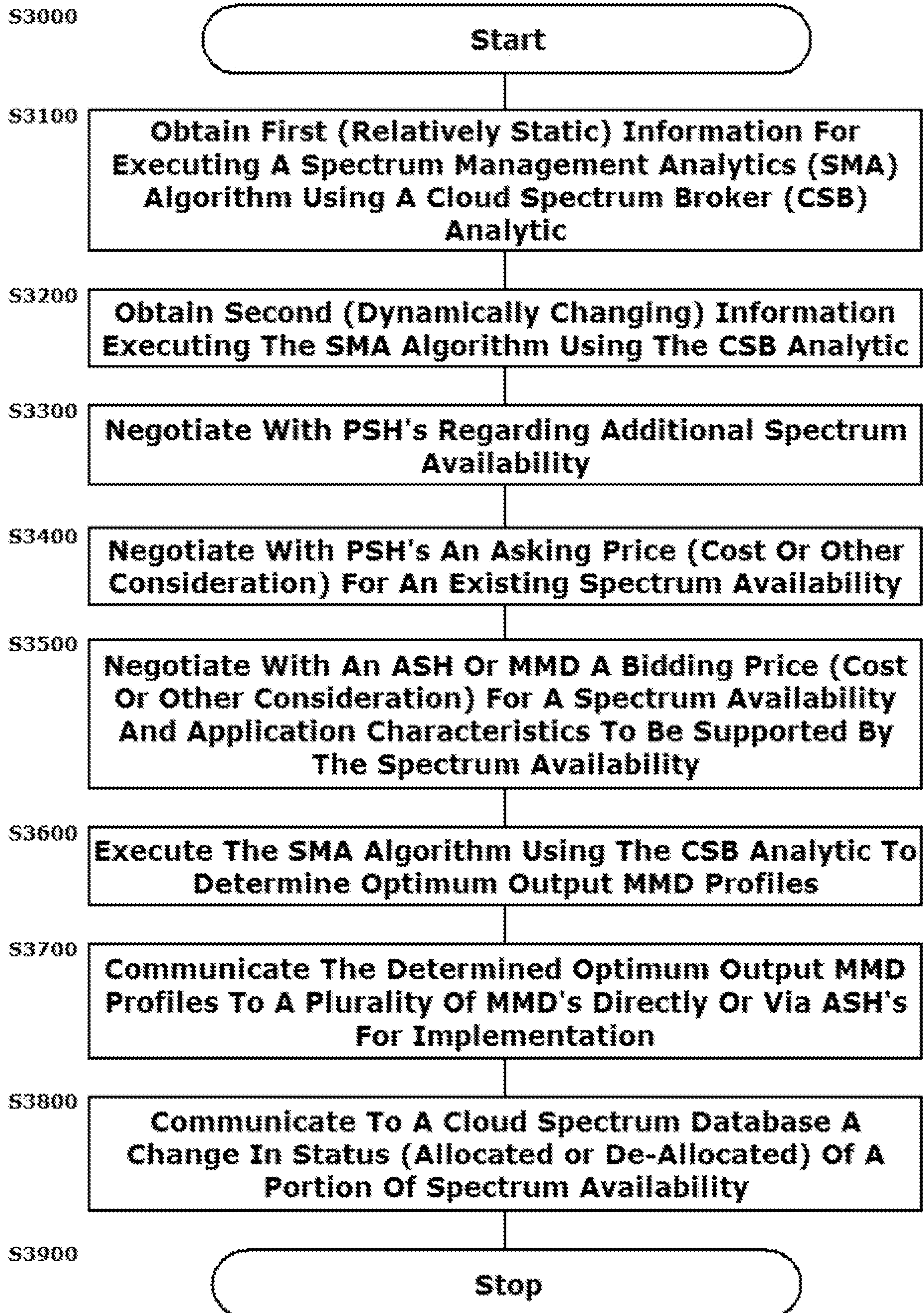


FIG. 3

100

115

Radio interface	
PK	<u>MMD ID</u>
PK	<u>Band ID</u>
PK	<u>RAT type</u>
FK1	Power consumption (idle)
	Power consumption (TX)
	Power consumption (RX)
	Receive sensitivity
	Serial number

120

MMD capabilities	
PK	<u>Serial number</u>
	Device class
	Device power source
	Accounting info

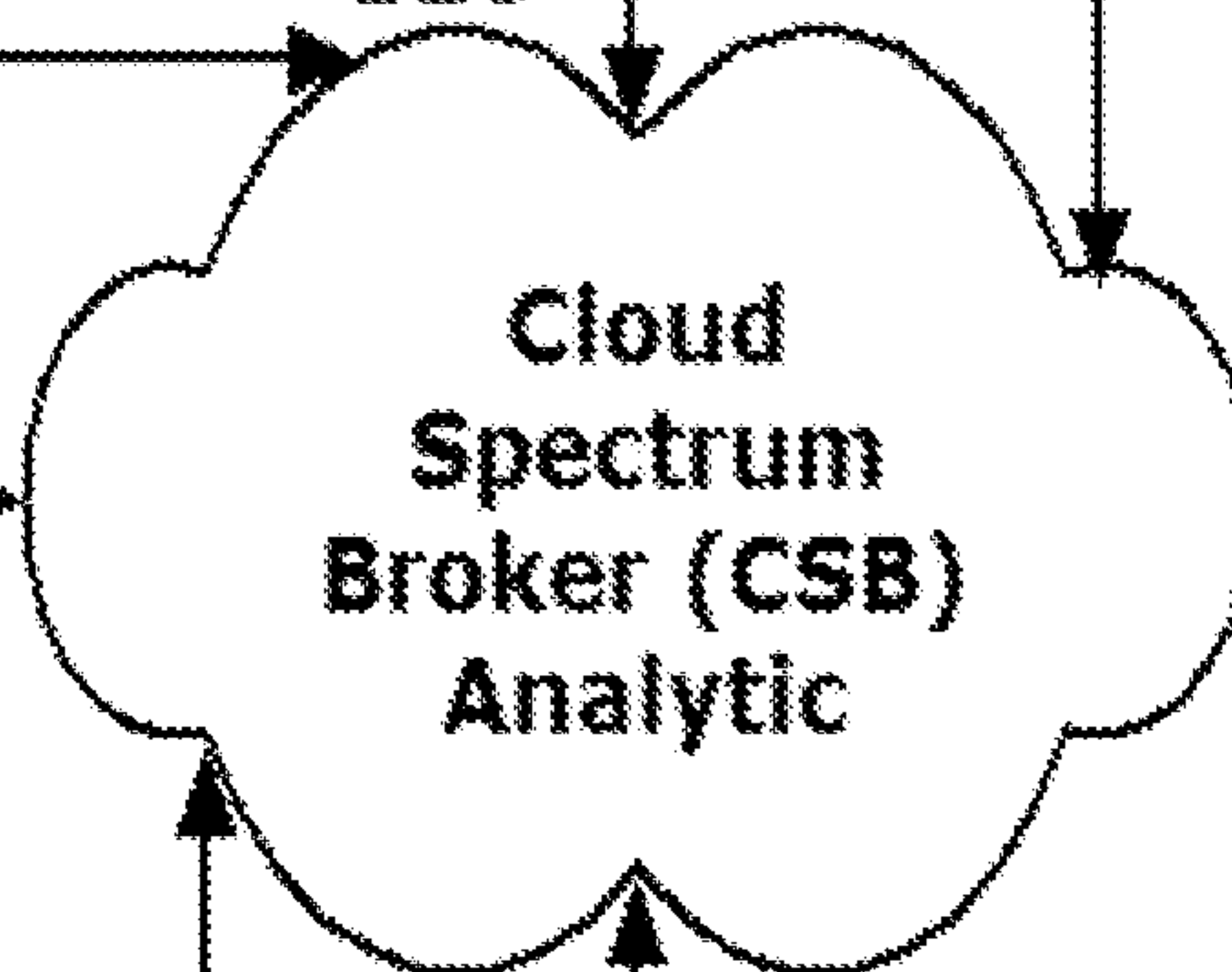
125

BS capabilities	
PK	<u>BS ID</u>
PK	<u>ASH ID</u>
	Band ID
	RAT Type
	Location (lat, long, alt)
	Coverage params

130

Geographic Databases

110



135

Spectrum Availability

140

MMD Profiles (0...N)

180

MMD profile	
PK	<u>Serial number</u>
PK	<u>MMD ID</u>
	ASH ID
	BS ID
	Band ID
	Channel frequency
	Start time
	End time
	RAT type
	Max TX power
	Charged price per TFU

145

Outstanding requests	
PK	<u>Serial number</u>
PK	<u>Device ID</u>
	ASH ID
	Expiration time
	Current location (lat, long, alt)
	Destination location (lat, long, alt)
	Speed (m/s)
	Bidding price per TFU

150

Application characteristics	
	Traffic type
	TX power level
	Min data amount
	Min number of TFUs
	Min data rate
	Desired data amount
	Desired number of TFUs
	Desired data rate

155

MMD mobility model	
PK	<u>Day of the week</u>
	Start time 1
	End time 1
	Location 1
	Start time N
	End time N
	Location N

160

Visible networks	
PK	<u>BS ID</u>
PK	<u>Band ID</u>
	RSSI
	Frequency channel

FIG. 1