Project	**IEEE P1900.4 WG** http://www.ieeep1900.org/
Title	**Information Model and Representation** (defining scope and high level requirements, methodology)
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Source(s)	Vinod GORLA, Klaus Nolte, Oliver Blume, Tim Farnham, Mahesh Sooriyabandara, Makis Stamatelatos, Oliver Holland, John Strassner, Vladimir Ivanov, Stanislav Filin, Kentaro Ishizu, Go Miyamoto, Homare Murakami, Tran Ha Nguyen, Hiroshi Harada Sub-group contributors : Motorola , Alcatel-Lucent, Toshiba, UoA, KCL, NICT, Intel Other sub-group members : Hitachi, KKE, Willnet, Tokyo University of Science, BAe Systems, Worldpicom, Pultek, Cosmo Research
Re:	IEEE P1900.4 Berlin meeting 3-7 December 2007
Abstract	This documents considers the scope and content of the information model
Purpose	Text proposal for the baseline document chapter on information model
Notice	This document has been prepared to assist the IEEE P1900.4 Study Group. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
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Part(s) of the P1900.4 D0.01 (approved in Madrid) addressed by the document?

Please tick the section of the Baseline Document D0.01 addressed by this contribution.

4. System Architecture *Overall system architecture with main interfaces (subject to standardization) between the building blocks. Note: in this section generic interfaces should be considered only.*	
5. Use Cases	
5.1 Dynamic Spectrum Allocation	
5.2 Dynamic Spectrum Access	
5.3 Distributed Radio Resource usage optimization	
6. General System Requirements *This section contains a) generic requirements (use-case agnostic or common to all of the use cases). Note: the nature of this section (text only AND/OR high level modeling should be defined during the course of document "development".*	
7. Functional baseline Architecture	
7.1 Dynamic Spectrum Allocation design realization	
7.2 Dynamic Spectrum Access design realization	
7.3 Distributed Radio Resource usage optimization design realization	
8. Information Model and Representation	✓
9. Procedures *This section contains the procedures the TRM should follow in order to "consume" the information (of section 8) conveyed of the radio enabler. This section should also capture the behavior of the TRM with respect to the policies. Note: Working assumption: The protocol aspects are considered to be informative and should be taken into account by the protocol task group which will design the actual protocol.*	

9.1 State Diagram(s)	
10. Annex	
Other : *(please detail)*	

This contribution is based on the baseline document D1.0. It contains an updated proposal for chapter 9 on the information model. The different information flows are extended in accordance with the interfaces as defined in D1.0 to reflect the defined entities. New appearing information flows still need corresponding explanations.

From the former release of this contribution an abstract of the chapter on common modeling techniques is inserted here, the rather technical details are omitted and moved to a newly created working document intended to be the starting point for the final info model document.

Issues:

1. *Are really all of the inserted information flows in the scope of P1900.4? If not – shall we state a clear reasoning in the beginning of the document?*
2. *Do we need additional information flows from NRM to RMC and from TRM to TMC in order to control measurements?*
3. *Skip general IM requirement # 5 or not? Including time/duration reference related to the validity of the provided information is potentially an important issue, we probably can't ignore it.*
4. *D1.0 contains an IM requirement: Exclusions and dependencies (e.g. Modes of Operations) – this should be either deleted or better explained*
5. *Shall we replace the general IM requirements 3, 4, 7 by:* GIMReq[4+3+7]: General Information model SHOULD include data types, composite types and be based on a platform independent unambiguous information/data type definitions.
6. *Better explanation on the distribution requirement for information object definitions (? Shared knowledge ?)*
7. *In the NRM to TRM sub-section the following sentence has been added:* "NRM MAY keep track of history information about the policies sent*." It has to be discussed to what extend this is needed in the information model section*

Comments that have been inserted in chapter 9 of D1.0 are left.

Where necessary, additional comments added to the text for explanation of the changes.

The following color-code is used within the text:

Yellow text is remaining yellow from D1.0

Text inserted

~~Text deleted~~

Text begin

9 Information Model and Representation

Comment [1]: [GC] Section colour code GREEN: discussed during St Petersburg WG meeting.

*** Generic information models and content (c.f. baseline functions in TOC 2.0 (Representation definition of context and policies) ***

~~NOTE: This document describes rationale and basic building blocks of the P1900.4 information model, which provides an abstract representation of the data associated with P1900.4 services.~~

9.1 Introduction

This section describes:

- rationale and basic building blocks of the P1900.4 information mode
- requirements associated with the P1900.4 information model
- element structures
- relationships between various information elements.

The P1900.4 information model is built using the DEN-ng methodology [X]. Within this context, a class model is developed to represent information elements that must be conveyed between the NRM and TRMs. Figure X depicts the relationship between information models and data models, whereby an information model is a set of abstractions and a representation of entities in a given environment, consisting of their characteristics and behavior. It is independent of any specific repository, application, protocol, or platform usage. In contrast, a data model is a concrete representation of an information model, bound to a specific type of platform, repository and protocol. Moreover, a data model may be realized in a protocol- and vendor-specific context.

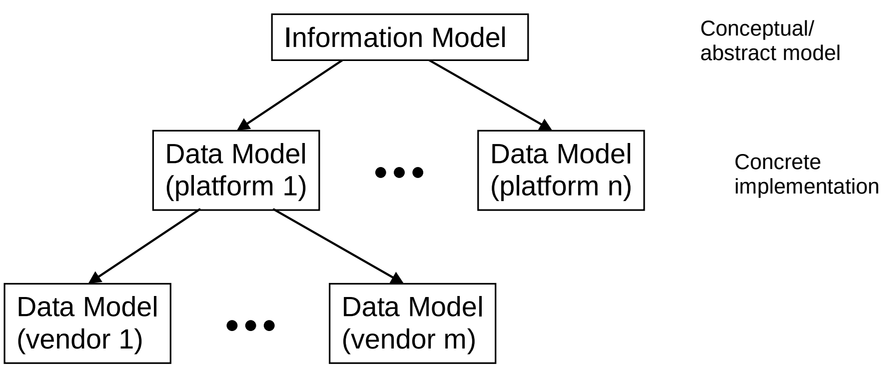

Figure X: Concept of model mapping

An important characteristic of an information model is that it specifies relationships between objects. Applications may use the contents of an information model to delimit the functionality that can be included in entity implementations. The degree of specificity (or detail) of the abstractions defined in an information model depends on the modeling needs of its designers. The purpose of the information model in P1900.4 is to abstract the managed objects associated with the entities as defined in Section 6. Within P1900.4 we therefore define the information model and recommendations for mappings onto data models. We do not specify the data models themselves.

9.1.1 Information Flow Categories

A diagram depicting the overall types of information flow is for further study.

Information flows are divided into categories based on source-destination pairs defined in Figure 6.2 System Architecture. These categories are as follows.

NRM to TRM information flow

Information delivered within this information flow includes:

- Radio resource selection policies
- Spectrum assignment related context information
- RAN related context information
    - May include other terminals related context information.

TRM to NRM information flow

Information delivered within this information flow includes:

- Terminal related context information.

RMC to NRM information flow

Information delivered within this information flow includes:

- RAN related context information.

NRM to RMC information flow

Information delivered within this information flow includes:

- Requests for RAN related context information.

NRM to RRC information flow

Information delivered within this information flow includes:

- Requests for RANs and BSs reconfiguration.

RRC to NRM information flow

Information delivered within this information flow includes:
- Responses to reconfiguration requests from NRM.

TRM to TRC information flow

Information delivered within this information flow includes:
- Requests for terminal reconfiguration.

TRC to TRM information flow

Information delivered within this information flow includes:
- Responses to reconfiguration requests from TRM.

TMC to TRM information flow

Information delivered within this information flow includes:
- Terminal related context information.

TRM to TMC information flow

Information delivered within this information flow includes:
- Requests for terminal related context information.

NMA to NRM information flow

Information delivered within this information flow includes:
- Spectrum assignment related context information.

NRM to NMA information flow

Information delivered within this information flow includes:
- Spectrum utilization evaluation results
- RAN capabilities.

[Section 9.1.2 should be moved to before the above section?]

9.1.2 General Information Model requirements

The information model is based on the following requirements derived from the use cases described in section ~~X~~4. ~~It should support:~~

- ~~Extensibility~~
  - ~~Accommodate future radio access technologies~~
  - ~~Allow custom extensions to existing data models~~

GIMReq1: General Information Model SHALL be developed in an extensible form to accommodate future radio access technologies and allow custom extensions to existing data models.

- ~~Relationships~~
    - ~~Sufficiently capture simple relationships between different data entities~~

GIMReq2: General Information Model SHALL support sufficiently simple relationships between different data entities.

- ~~Non-uniform data structures~~
    - ~~e.g. Multi-valued variables (e.g. lists)~~

GIMReq3: General Information Model MAY include both uniform and non-uniform data structures (e.g. lists)

- ~~Qualifying data (Meta-knowledge)~~
    - ~~e.g. Information about data (e.g. accuracy and precision)~~

GIMReq4: General Information model SHALL use data items by data types to describe information items.

GIMReq4a: General Information model SHALL use data items with qualifying metadata to give indication of precision and accuracy (or indication on the reliability of the data – e.g. estimated) where necessary

- ~~Various transaction models~~
    - ~~Synchronous & Asynchronous~~
    - ~~Short and Long duration (to be quantified)~~

GIMReq5: General Information model MAY include time/duration reference related to the validity of the provided information. For instance the time at which measurements were made or valid period in which they are to be taken.

- ~~Exclusions and dependencies~~
    - ~~e.g. Modes of Operations~~

GIMReq5a: General Information model SHALL include exclusivity or consistency relationships between objects to determine conflicts – for instance whether two different channels or radio technologies can be monitored at the same time.

- ~~Unique identifiers~~
    - ~~Useful as a reference~~

GIMReq6: General Information Model SHALL incorporate unique identifiers in the most appropriate basis (information objects, information elements within objects etc…)

- ~~Platform independent unambiguous type definitions~~

GIMReq7: General Information Model SHALL utilize platform-independent unambiguous information/data type definitions

- ~~Efficient and fast retrieval and updating of information objects~~

Comment [2]: [KN] This is functional requirement, shall be skipped here

- ~~Openness~~

- ~~Text: What is the specific definition of openness here? To be further defined.~~

Comment [3]: [KN] This is protocol related requirement, shall be skipped here

- ~~Ability to be distributed~~
  - ~~Text: Does 'distribution' mean distributed amongst multiple nodes or freely available? To be further defined.~~

GIMreq8: General Information model MAY include information about information objects distribution (i.e. to identify the targeted nodes to a multicasting case)

- ~~Compliance with relevant standards, e.g. IEEE 802.21~~

GIMReq9: General Information model SHOULD be aligned with relevant standards in cases of information elements identification and/or representation schemes (e.g IEEE 802.21)

GIMReq10: General Information Model MAY incorporate additional information elements to ensure alternative information retrieval to support the retrieval mechanism.

GIMReq11: General Information Model SHALL incorporate corresponding information elements towards developing a shared knowledge framework about the information objects themselves. Such framework MAY include information about the objects local storage, updates, status etc.

GIMReq12: General Information Model SHALL incorporate security-related information elements depending on the functional description.

GIMReq13: General Information Mode SHALL/MAY incorporate a notifications list, such as alarms, configuration changes security events etc to align the shared knowledge framework.

GIM Req14: General Information Model MAY incorporate additional information elements to ensure alternative information retrieval to support an efficient retrieval mechanism to obtain performance, QoS and related information and measurements data.

GIMReq15: General Information Model SHALL incorporate information elements that can be provided value (instantiated) through mechanisms such as statistical operations to reduce data transfers.

Comment [4]: [KN] General Requirements coming from specific information flow sub-sections, need to be revised by the group

It would be useful to control the data definitions for various RATs either through a dedicated central body or by sharing the data model with relevant standards committees. An important concept in supporting this is ~~an abstract representation of information within a class hierarchy~~ a data abstraction model using classes. This concept encapsulates data items (that logically belong together) and operations on them into objects (instances of the classes). Two other fundamental concepts based on the class concept are inheritance and composition relationships between classes. These two concepts along with support for multiple classes broaden the extensibility of the data model in supporting future radio access technologies. ~~A hierarchical class representation along with support~~

~~for multiple classes characterises the extensibility of the data model in supporting future radio access technologies. Two fundamental ways for establishing relationships between classes are inheritance and composition.~~

In an inheritance relationship, classes are extended with new attributes and/or methods that differentiate them from their parents (super-classes). Inheritance allows for different levels of data abstraction. As a consequence, a higher re-use of upper abstraction levels is possible.

In a composition relationship, ~~the front-end class stores instances of the backend classes~~ an instance of the superior class contains instances of the subordinated classes. ~~In a composition relationship, the front-end class stores instances of the backend classes.~~ The composition method provides a simple way to combine different classes to create new objects easily.

Most likely the information models will be defined in an extensible schema.

9.2 Methodology

UML-based modeling is used. Classes are defined in order to abstract various common aspects associated with, e.g., communication (such as the link, channel, cost, security, and quality of service), policies, context data, measurement reports, etc. This permits re-use of the same data and data representations for multiple RATs. This is particularly useful for fulfilling the requirements of efficient capability query, exchange, and notification mechanisms.

The definition of a class consists of the definition of its attributes (including the value type at an abstract level). Generic methods are used to get and set various attribute values (this will cover the majority of operations on an object of a given class). Additionally, if necessary, specific actions can be defined. Objects can be dynamically constructed and destructed by management operations. Access rights for operations and attributes will have to be defined.

An inheritance relationship, as consistent with UML modeling, is used in order to re-use parts of the information definition. Finally, class definitions may also define aggregation and composition relationships to other classes.

The preferred syntax to describe the classes used for information modelling is XML, as employed within the DEN-ng methodology. Inheritance should be used to extend the DEN-ng classes. Other approaches may also be considered.

In order to emphasise the abstraction character of the information model, it is proposed to use a subset of ASN.1 for the specification of the utilised abstract data types. The characteristics of relevant standards must be considered in the creation of the information model.

Modeling Common Functions

To facilitate efficient exchange of information, it is necessary to incorporate classes to apply the required statistical operations, filters (i.e. selection criteria), trigger thresholds, and other mechanisms that can optimize the efficiency of information exchanges.

~~9.2~~

9.3 Common Objects (placeholder for contribution from Motorola – other contributions invited)

9.3.1 Common Policy Objects

9.3.1.1 Application Scenario

9.3.1.2 Regulator Policy

9.3.1.3 Operator Policy

9.3.1.3.1 Network management policies

9.3.1.3.2 Equipment management policies

9.3.1.4 User / terminal Policy

9.3.1.4.1 User preferences & profiles

9.3.1.4.2 Terminal capabilities & profiles

9.3.2 Policy Objects within the standard

9.4 Managed Objects in Terminals

[product of discussion including Klaus, Mahesh, Tim, Oliver—initial version!!!] – Final structure to be specified for next versions of baseline – proposals invited

- Meta data
  - Role
  - Capability
  - constraints
- Link
  - characteristic
    - RAT
    - Channel
    - State
  - …
- Terminal profile
  - …
- Policy rule
  - Policy event
  - Policy condition
  - Policy action
- Terminal Context
  - Location

Comment [D5]: This is to be considered as common managed object (see 9.2)

- Radio environment
  - Channel

- Link
- Speed/direction
- Services initiated
  - State
  - QoS requirements…
  - …
- User profile
- …

9.4.1 Policy rules

The NRM to TRM information will include specified policy rules that will direct terminal reconfigurations. Policies generated within the NRM are directed from the NRM to TRM. NRM MAY keep track of history information about the policies sent. The following subsections present more specific requirements on the information in question; the methodology for the information structure is presented, that is the information fields that compose the NRM to TRM/RAT information as well as specific examples.

9.4.1.1 Requirements

The Requirements related to the Policy Information structure derive from the identified use cases as well as from the generic Requirements for the Information Model as listed in section 8.1.2. In this sense, Policy Structure requirements include:

- ~~Extensibility: New features/rules shall be easily incorporated~~

- ~~Overhead: Policies will be communicated to the TRM through the RE; this means that the adopted structure should minimize the signaling overhead and be aligned with the minimal RE functionality according to RE specification~~

- ~~Storing: Policies will have to be stored locally in the TRM; the adopted structure should minimize the storage requirements.~~

Req1.1: NRM-to-TRM Information Model SHOULD adopt a structure that will ensure minimization of the storage requirements given that policies will have to be stored locally in the TRM (justification for GIMReq11).

- ~~Simple form: preferably a policy should be broken down into a set of individual rules coupled with a set of minimum conditions instead of multiple disjunctions/conjuctions between the conditions~~

Req1.2: Within the NRM-to-TRM Information model a derived policy SHOULD be broken down into a set of individual rules coupled with a set of minimum conditions instead of multiple disjunctions/conjunctions between the conditions.

Comment [6]: [KN]Already covered by the General requirements, to be skipped

Comment [7]: [KN] This is related to functional requirements, to be skipped

- ~~Security: the policies should be securely distributed to TRMs (this also includes reliability of delivery)~~

Comment [8]: [KN]This is related to functional requirements BUT a general req has been added based on security issues.

Transmission of the policy from NRM to TRM is performed by either advertising the policy by NRM to TRMs in a periodical manner, or requesting the policy from the TRM to NRM.

NRM provides policy and advisory. Policy is a description that the TRM needs to obey. The detection of policy infringement and the countermeasures are out of scope of this document. TRM may be required to keep and provide a policy infringement and contradiction log to NRM. This point is for further study.

Reliability of the information transport is determined according to the total system requirement. Some information is required to be reliable to reach the destination, and others are not required. These two types of information with different requirements can coexist in the P1900.4 system.

From a logical point of view NRM is one entity and can be implemented in a distributed way, as long as there is no conflict in policies provided by the NRM.
Note: The process of how a policy is derived from the information/content in NRM is not in the scope of the Information Model. It MAY be implementation specific.

9.4.1.2 Methodology - Motorola to propose text in keeping with DEN-ng

In terms of supported functionalities, policy provision and policy representation are strongly relevant to Network Reconfiguration Management. The envisaged content of the Radio Enabler downlink includes policy information addressing/supporting radio resource management in composite networks (07-02-13). In the context of P1900.4 activities, it is therefore necessary for both the policy content and the structure/representation of associated information to be well defined. This subsection therefore provides the framework for specification of the policy structure.

A basis for policy definition could be for instance based on IETF work - http://tools.ietf.org/html/rfc3060 - for further study.

In a P1900.4 context, policies are generated within the Network Reconfiguration Management module and are communicated to the Terminal Reconfiguration Management module via the Radio Enabler, as presented in previous sections. A Policy is composed of a number of specific rules, which, generally, express actions to be triggered when certain conditions are met.

A policy in its simplest form, as defined within NRM, includes two parts, a condition to be met and an action to be enforced; thus a policy is considered as a {condition C, action A} pair and is of the depicted ~~in XXX~~ form in **Error! Reference source not found.**.

Deleted: Figure 1-1

Furthermore, a policy may define several conditions and include several action rules; in such a case, policy structure will also include the corresponding relations that inter-connect the conditions; the included rules may be related by logical operators such as the logical AND, OR, NAND, NOR etc. The form of such a policy is depicted in **Error! Reference source not found.**.

Deleted: Figure 1-2

IF <condition> THEN <action>

Figure 1-1: Simple Policy Form

{(condition C1 OR condition C2) AND condition C3;
action A1 OR action A2)}

Figure 1-2: Policy with interrelated conditions

Based on the above analysis, NRM-defined Policy is organized in two main sections: the first section includes Policy Parameters and the second one specific Rule Parameters. Policy parameters provide general information about the communicated policy and include the following fields:

1. Policy ID defines a unique policy identifier and is used for efficient policy storage and retrieval;
2. ~~Policy Validity may be expressed either by the the time interval during which a policy remains valid and can be utilised by the NRM or alike by a region within which a policy remains valid;~~
   Policy Validity may be expressed either by the time interval during which a policy remains valid, by a region within which a policy remains valid or by a recurring time period, such as weekends or between 21:00 and 08:00 on weekdays;
3. Policy Rules Number is set to an unsigned integer defining the number of rules that are included in the identified policy.

Rule parameters section is repeated for each rule composing the policy and includes fields:

1. Rule ID provides a unique rule identifier;
2. Rule Definition Length provides the length of the serialized rule definition that will follow. The length of the rule is for future study and definition during the specification stage. Rule Definition provides a rule representation in the form of IF <condition> THEN <action>. In this definition the following (tagged) information will be included:
   a. Priority defines the marking of an individual rule within the Rule Definition. Therefore, Priority set may include tags such as
      - “SHALL” implying an action to be triggered when certain conditions are met;
      - “SHALL NOT” implying a limitation based on certain conditions;

- “MAY” implying an action that may or may not be implemented by the TRM.

b. Rules interrelation may be equal to logical conjunction – “OR” or disjunction – “AND” (or other logical operators such as “XOR”, “NAND” or “NOR”, etc),

3. Time Constraints: A notion of time is important in the policy. This is related to the time constraint in the execution of policies.

9.4.1.3 Examples

An example generic form of an NRM policy is presented in Figure 8.2.3.

```
{ Policy ID,
   Policy Validity
   Policy Rules_number,
  {  Rule ID 1,
     Rule Definition Length
       {condition1},
          {action1.1}{priority (MAY/SHALL/SHALL_NOT)},{Time Constraints1.1}}
         OR/AND/NOR/….
         {action1.2},{priority (MAY/SHALL/SHALL_NOT)},{Time Constraint1.2}},
         …… …
  { Rule ID 2,
     Rule Definition Length
       {condition2},
       {action2},{ priority (MAY/SHALL/SHALL_NOT)},{Time Constraints 2}},
}
```

Figure 8.2.9-3: NRM Policy - Generic Form

Priority examples:

- Mandatory (SHALL, SHALL_NOT) / optional (MAY)

Condition examples:

- Terminal state
  - Terminal in connected mode on a particular RAT
  - Terminal in idle mode
- Location
- Terminal class
  - Service class
- Time of day
- Terminal capability
- Radio quality
- Subscription information: e.g. user has GPRS capability but no subscription/wrong configuration of settings.

Comment [TF9]: Subscription information may be available at the terminal and may not need to be explicitly passed from the NRM to TRM.

Action examples:

- Change permitted RAT
- Change permitted frequencies/channels
- Perform specific measurements and query NRM with the measurement results before opening a new radio link

Actions may be modeled via status attributes of the information objects – an action is triggered by a state transition)

Time constraint

- Action should be performing within period,
- Action should be performed after period,
- Action should be performed at random interval within period~~)~~

Terminal Measurements (used in policy actions)

- Supplementary Parameters not already reported using present standards(3GPP)
- Reporting criteria
  - Event based
  - Timer based

Policy Validity examples:

- Time of expiry
- Location / region

9.4.2 Radio Environment

9.4.2.1 Requirements

~~The general requirements derived from the use-cases are as follows:~~

This section provides additional requirements to the general Information Model requirements; it also translates some of the general requirements into the specific scope of the TRM-to-NRM information flow type in order to point out specific features.

- To support an efficient mechanism to obtain performance, QoS and related information between NRM and TRM, when this information is not available from the RAT directly.

- ~~To allow measurement data to be sent when and as often as required by the NRM and also in accordance with the TRM's capabilities and resources available to perform measurements.~~

- ~~To keep the network overhead to a minimum while still fulfilling the requirements of the NRM with the necessary TRM related data~~

- ~~To minimize the complexity of TRM for processing interactions between NRM and the TRM.~~

- ~~NRM can also coordinate the distribution of information (for example measurement reporting information) between TRMs.~~

Comment [10]: [KN] GIMReq13 has been extracted from the above requirements that will be skipped

Radio resource management (including dynamic mode or channel selection) schemes rely on monitoring of the radio environment to estimate the performance and opportunities. This is especially true for cognitive radio scenarios where accuracy and precision of measurements are very important before deciding on the spectrum opportunities. Efficiently supporting the taking and retrieval (reporting) of measurements requires several mechanisms. These are:

- ~~Taking only the necessary measurements at the necessary times~~

Req2.1: TRM-to-NRM Information Model SHALL include information element(s) in order to coordinate the measurements scheduling.

- ~~Performing any statistical operations at the TRM to reduce data transfers~~
- ~~Allowing the specification of triggers for asynchronous notification of results~~
- ~~Transferring the measurement data in the most efficient manner with regard to both timeliness and communication overhead for the available communication means (for instance sending bulk measurements may be more efficient than sending individual measurements).~~

Comment [12]: [KN] GIMReq15 has been formed based on the above.

Comment [13]: **[KN]**Already covered, to be skipped

Comment [14]: **[KN]**it is related to protocol work, to be skipped.

Therefore, the P1900.4 data model not only needs to capture the communication capability and performance information of the radio device, but also the measurement capability to facilitate the control of the measurement method (e.g. monitor duration, monitor method) and the statistical operations performed on the monitoring results. Clearly, it would be inefficient to report instantaneous or unwanted measurement values and this must be avoided wherever possible.

9.4.2.2 Methodology

9.4.2.2.1 Data Abstraction

~~Object Oriented Design (OOD) principles provide some valuable tools for data representation. For example, the notion of classes allows grouping of objects with common attributes and behaviors. A class model could be used to abstract various common aspects associated with communication such as link, channel, cost, security and quality of service. This can permit re-use of the same data and data representations for multiple radio access technologies. This is particularly useful for fulfilling the above requirement of efficient capability query, exchange and notification mechanisms.~~

It is possible to use the same data abstractions (classes) for capability querying and notification (or measurement) reporting. This reduces the complexity by combining all interactions into the common information model and avoiding duplication of information processing functionality. The additional abstractions necessary to support this are derived from a generic P1900Provider class. For instance channels objects will be created by a P1900ChannelProvider and links by a P1900LinkProvider. The attributes of the providers denote their generic P1900 capabilities, for instance the measurement / monitoring, statistical operations, filtering and other capabilities.

The abstract concept of a "channel" is fundamental to communication systems to provide the medium to facilitate communication. Therefore, the channel could be treated as the primary data object in the P1900.4 information model. The P1900Channel class abstracts radio resources that can be used by radio devices and a channel may be characterized in the frequency, time and space domains. A radio device may support several channels, which may or may not be utilized by one or more radio devices at the same time. Also, a single radio device may utilize one or more channels. Channels may be multiplexed in time, frequency or by other sharing schemes or indeed a combination of resource sharing schemes. Also, the channel object will often be associated with a communication link that abstracts the logical connection between two communicating nodes at the link layer.

Comment [D15]: Relationship to OMG Communication Channel within Software radio specification- This is for further study

~~**Summarization**~~
~~To facilitate efficient exchange of information, it is necessary to apply the required statistical operations, filters (selection criteria), trigger thresholds and other mechanisms that can optimize the efficiency of information exchanges.~~

This is for further study.

9.4.2.3 Examples

The P1900.4 scope is to define the top level abstract classes of the information model. The optional extension of this is out of the scope, but can be made possible by the extensible information model methodology (as depicted in **Error! Reference source not found.**). This type of abstraction permits the key performance indicators requested from the TRM to be defined and accessed in a hierarchical and extendible manner. For instance, the main channel related information (which can correspond to frequency or other multiplexing schemes – in the temporal and spatial dimensions), required in most of the use cases are, for instance :

Deleted: Figure 4

1) Radio power indicator (RPI) – The RPI can consist of a histogram of number of bins each specifying the power density over the monitoring interval for the power level range corresponding to the bin
   a. Within the p1900Channel class this is generic radio power for all technologies (for instance a histogram or power density specified in different power range bins for each channel)
   b. Within the 80211Channel class this corresponds to RPI for only 802.11 traffic
   c. Within the 802.11nChannel class this corresponds to RPI for only 802.11n traffic
2) Loading (or channel occupancy) - The occupancy can indicate the proportion of time over the monitor interval during which transmissions are detected on the channel (for instance transmission can be defined as modulated signal as opposed to noise)
   a. Within the p1900Channel class this is generic loading (or occupancy of the channel by any detectable transmissions)

b. Within the 80211Channel class this is loading corresponding to 802.11 traffic only
c. Within the 80211nChannel class this is loading attributed to 802.11n traffic only

Additional information falls into other classes, for instance, p1900Link information is independent of actual underlying link technology and can contain information such as :

1) Received frame error rate
2) Transmit frame error rate
3) Transmit frame count
4) Received frame count

Furthermore, there is scope for generic cost, security and other information classes that support the selection and connection to different RAN in a generic manner. For instance, security information may contain the necessary keys or description of the type of authentication mechanism supported or to be used for securing the radio enabler between NRM and TRM or to access different RANs. It may also contain security alerts or alarm information to inform NRM of potential threats.

The above example information elements may be required in all use-cases in which the information is not available from the RMC (or RAN directly). For TRM to NRM information flow, the channel and link (plus other) information classes can be encapsulated within the appropriate terminal class by way of encapsulation, this giving the unique reference to a particular terminal instance. This is most likely to be a necessity in order for NRM to determine the origin of the information elements.

DSA use-case

For DSA there may not be a requirement to return channel and link related information from the TRM to NRM, but link and other class information may be required. In some scenarios it may be assumed that the NRM already is aware of the terminals and network element locations and can determine the most appropriate channel frequency assignments based on this prior knowledge that is obtained from the RMC or directly from RAN entities. In other scenarios information from terminals is required to determine whether hidden nodes are likely to exist and/or to determine the coverage areas of the RANs.

Example scenario steps :

1) Terminals supports WiFi and UMTS and are connected on UMTS
2) NRM sends a policy to all terminals to measure channel information on a set of available WiFi frequency channels
3) Terminals report generic p1900 and 802.11 channel information over RE uplink over UMTS
4) NRM determines a new frequency assignment for WiFi access points and sends revised policy to inform terminals when to use WiFi

OSA use-case

For OSA it is likely that channel related information is required by the NRM from the TRM in order to determine the most appropriate policies for OSA. This use-case is potentially more dynamic that DSA, in that interference from transmissions on the same or adjacent channels may occur. NRM may require historic and planned channel utilization information from TRM in order to determine or predict the causes of interference by, for instance, correlation of interference events with usage patterns.

Example scenario steps:

1) Two RANs operate in same band and some terminals are on each RAN
2) NRM sends a policy to terminals to report channel and link interference related information whilst allowing terminals to select channels to use in an opportunistic way
3) TRM measurements alert NRM to excessive interference problem and result in an updated (more pessimistic) policy being sent to terminals
4) Now only a subset of terminals are allowed to dynamically select channel

Distributed Radio Resource Optimisation use-case

For distributed radio resource optimisation it will also be necessary to obtain channel and link related measurement information in order to determine the policy and schedule for optimisation.

Example scenario steps:

1) NRM issues policy to permit terminals to select RAN and channel to use in a round-robin schedule
2) The policy requests terminals report channel and link performance each optimisation cycle
3) The NRM adjusts the policy (i.e. cycle schedule) based on these measurements

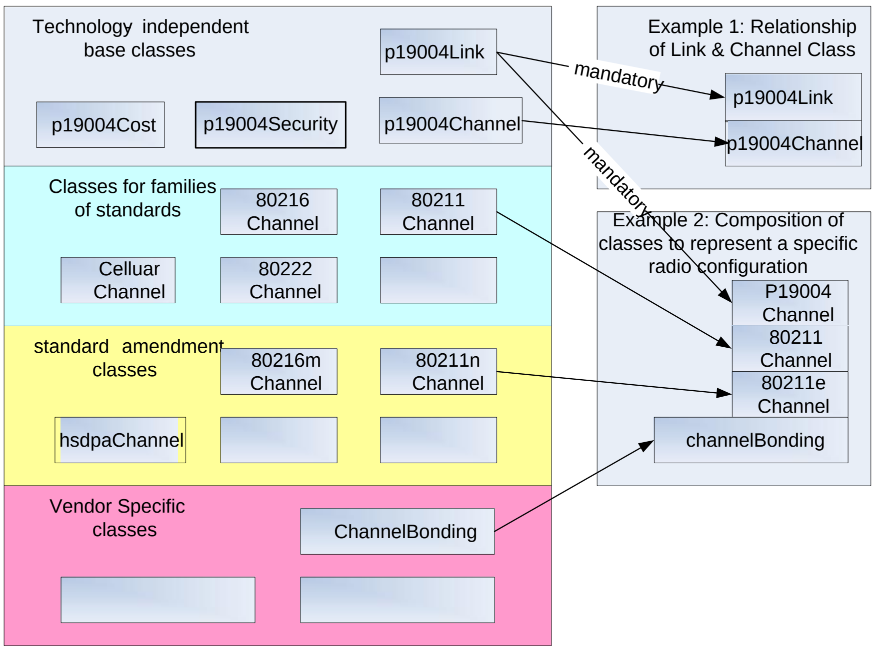

Figure 4 - Example Hierarchical Organization P1900.4 Classes

This is for further study.

9.4.3 As bullet points above…

9.4.4 …

9.5 Managed Objects in RANs

- RAN profile
  - RAT
  - …
- Cell/Mesh profile
  - Location
  - …
- Cell context
  - Coverage area
  - Transmission power/SINR
  - Load
  - Throughput
  - QoS statistics
  - Radio environment

  - Neighborhood
  - …
- …

9.5.1 Cell context

RAT to NRM information is for the purpose of measurement capability and information reporting, and has similar requirements to TRM to NRM information flows.

9.5.1.1 Requirements

~~Information regarding cell loads, performance parameters, quality of service. This should be abstracted as independently as possible from specific RAT technologies.~~

Different classes of data and measurements SHALL be accessed and evaluated by the NRM for control of cell resources, for taking RAN reconfiguration decisions, and for deducing new policies for the terminal operation and, finally, by the TRM for enabling policy based terminal reconfigurations:

- RAT specific measurement data about performance and usage collected by network devices within the RAT (RANMC) and forwarded to the NRM
- cell capacity, capabilities and cell load representation from the RAN (RANMC) and forwarded to the NRM
- RAT internal measurement data (link specific measurement reports) performed by the terminal on the serving link(s) and about potentially available radio links to other RATs that are forwarded to the RAN

All three classes of data and measurements are characteristically RAN specific (e.g. RRM data and measurements) or defined on basis of a RAN specific metric or classification (e.g. load and QoS). Data and measurements from different RANs SHOULD undergo a transformation providing an abstraction into generic and comparable quantities before being delivered to the RCE repositories, enabling a unique further processing.

Meaningful generic and comparable quantities will in general depend in a complex way on one or more physical, RAT specific measurements or node related data. The abstraction algorithms SHALL be designed to cope with such complex dependencies.

NOTE: The definition of the abstracted values and related requirements (e.g. accuracy) are specified within IEEE P 1900.4. The abstraction algorithms are implementation specific and not within the scope of IEEE P 1900.4. Also, the specification of the related RAT specific physical measurements is outside of the scope of IEEE P 1900.4.

This is for further study

9.5.1.2 Methodology

9.5.1.2.1 Abstraction from RAT Specific Measurements

In P1900.4 it is described how NMR defines policies and transfers these into TRM. TRM takes appropriate action to account for the policies, e.g. by configuring the radio spectrum

bands or by performing a different scheduling of data packets to the $RAN_1..RAN_n$. To enable the definition of policies in NRM and the application of the policies in TRM regarding any radio technology of the RE , the formulation of the policies needs to be RAT independent and shall use the same generalisation values as used for the abstraction of measurements.
Each application requires a specific set of QoS parameters, e.g. a conversational application demands a delay in the MAC layer of below 50 msec, a jitter of 5 msec with <1% BER, while interactive browsing needs <1‰ BER and accepts more than 150 msec delay. Thus, link ranking requires regarding a set of generic QoS parameter and another set of generic requirements. The rating needs to weight the influence of the set of contributions. For each application the link ranking may require a different weighting of the generic QoS parameter:

- (Mean and peak) data rate [kbit/s]
- Packet delay [ms] in the PHY and MAC layer of the RAT
- Delay jitter [ms] in the PHY and MAC layer of the RAT
- Maximum packet loss rate[%]or block/frame error rate [‰]

The maximum available data rate and the associated block error rate depend on the radio link quality, i.e. the position and the capabilities of the mobile terminal and can thus only be measured by the mobile terminal. Other QoS parameter like delay and jitter are rather determined by the load in the access point.

9.5.1.3 Configuration of Measurements

NRM needs to specify which measurements to perform. This comprises generic specifications that have to be mapped to RAT specific measurement configuration by the abstraction function.

- Frequency bands and cell IDs
- Periodicity and granularity of measurements
- Averaging
- Reporting events

9.5.1.4 Cell Selection and HO Decision in a Heterogeneous Network

For path and cell selection the abstracted measurements enter next to other parameters (like policy and capabilities). The selection is performed with a rating function that calculates a single rating value out of the set of input values. The metric for this mapping is out of scope of the current version.

This is for further study

9.5.1.5 Examples

Example information content:

- Cell load
- QoS parameters
- Performance parameters
- Specific information content available from existing standards (that could be mapped / abstracted) if necessary

This is for further study

9.5.2 …

9.6 Managed Objects in NRM

- These objects are required by NMA – Whether this section is required will be clarified as a result of contributions to the previous sections
- …

9.6.1 …

[The following section 9.7 needs to be reviewed in light of the new structure. Any content from the below needs to be checked and incorporated into terminal managed objects section if necessary…]

9.7 TRM to TRM Information

The information flow from TRM to TRM is a logical flow of information required for measurement statistics reporting and related activities. This sub-section will evolve depending on outcome of discussions of dynamic spectrum access use case and infrastructure-less investigation.

9.7.1 Requirements

The general requirements derived from the use-cases are as follows:

- To support an efficient capability query and notification mechanism between TRMs
- To allow measurement data to be sent when and as often as required and also in accordance with the devices capabilities and resources available to perform measurements
- To keep the network overhead to a minimum
- To ensure that other TRMs are informed when the relevant TRM status changes
- To minimize the complexity required of the TRM for information processing.

In addition to section **Error! Reference source not found.** above, radio resource management (including dynamic mode or channel selection) schemes can benefit from direct exchange of information between devices. This information exchange cannot only permit more efficient monitoring of the radio environment to estimate the performance

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and opportunities, but also to allow end-to-end collaboration or cooperation between TRM devices. Efficiently supporting the taking and retrieval (reporting) of measurements requires several mechanisms. These are:

- Taking only the necessary measurements at the necessary times
- Performing any statistical operations at the TRM to reduce data transfers
- Allowing the specification of triggers for asynchronous notification of results
- Transferring the measurement data in the most efficient manner with regard to both timeliness and communication overhead for the available communication means (for instance sending bulk measurements may be more efficient than sending individual measurements)

9.7.2 Methodology

The requirements can be supported with the same methodology as for **Error! Reference source not found.** above.

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9.7.3 Examples

Text end