[Draft Working Document]

IEEE P802.16.3 Architecture and Requirements for Mobile Broadband Network Performance Measurements

**IEEE 802.16 Working Group**

**Project P802.16.3**

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[Draft] IEEE 802.16.3 Architecture and Requirements for Mobile Broadband Network Performance Measurements

# Scope

The IEEE P802.16.3 draft standard shall be developed in accordance with the P802.16.3 project authorization request (PAR) and Five Criteria Statement (IEEE 802.16-12-0489-01-Gdoc), as approved on 30 August 2012 [1]. According to the PAR, the scope of the resulting standard shall be:

*This standard specifies procedures for characterizing the performance of deployed mobile broadband networks from a user perspective. It specifies metrics and test procedures as well as communication protocols and data formats allowing a network-based server to coordinate and manage test operation and data collection.*

The standard will address the following purpose:

*By standardizing the metrics and methods, the standard provides a framework for characterizing and assessing the performance of various mobile broadband networks. By standardizing the protocols and data formats, it allows for a measurement server to collect information from a disparate set of devices on the network.*

and the following need:

*Users of broadband mobile networks, including enterprises such as corporations and governments, and mobile application service providers, lack reliable, comparable data on which to base their assessment of network performance. Such data can be valuable to determine overall network quality and to pinpoint specific weaknesses, including limitations in deployment. Improved knowledge of system performance will lead the market toward more effective networks and therefore encourage the redeployment of scarce spectrum using the most efficient technologies and implementations. Also, policy makers seeking information on performance of available networks will directly benefit by the opportunity to apply the standardized metrics and methods. Researchers will also gain by the ability to compare measured performance data to simulated results and thereby assess the theoretical models. One application of such information is the assessment of technology elements proposed during standards development.*

This document specifies, in addition, the requirements to be satisfied by the IEEE P802.16.3 draft standard. In order to explain and specify those requirements, it also indicates suitable applications, and it details the architecture, functional entities, and communication links to be specified, along with a list of data to be exchanged among the entities.

# References

[1] IEEE 802.16-12-0489-01, “Approved PAR P802.16.3, with Five Criteria: *Mobile Broadband Network Performance Measurements*” ([link](http://doc.wirelessman.org/16-12-0489-01))

[2] Steven Bauer, David Clark, and William Lehr, “Understanding Broadband Speed Measurements,” MITAS Working Paper, June 2010 ([link](http://mitas.csail.mit.edu/papers/Bauer_Clark_Lehr_Broadband_Speed_Measurements.pdf))

[3] William Lehr, Steven Bauer, and David D. Clark, “Measuring Internet Performance when Broadband is the New PSTN,” *The End of the Phone System: A by-invitation Experts’ Workshop*, The Wharton School, University of Pennsylvania Philadelphia, PA, May 16-18, 2012 ([link](http://mitas.csail.mit.edu/papers/lehr_bauer_clark_pstn_transition_6_2012.pdf))

[4] “Next-Generation Measurement Architecture Standardization and Outreach Group (NMASOG) – Architecture Standards and Specifications,” Federal Communications Commission, 2012 ([link](http://apps.fcc.gov/ecfs/document/view?id=7022008017))

[5] Henning Schulzrinne, Walter Johnston, and James Miller, “Large-Scale Measurement of Broadband Performance: Use Cases, Architecture and Protocol Requirements,” September 21, 2012 ([link](http://datatracker.ietf.org/doc/draft-schulzrinne-lmap-requirements/))

# Definitions and Abbreviations

## Definitions

1. **[Term**: definition]

## Abbreviations

MBNPM Mobile Broadband Network Performance Measurements

PII Personally Identifiable Information

# Applications

In Table 1, we have listed key applications in tabular form, along with a list of various stakeholder roles, drawn significantly from PAR Item 5.6 (“Stakeholders for the Standard”). Table 1 also indicates an assessment of the applications of greatest interest to each stakeholder role.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Stakeholder role** | | | | | | | |
| **Measurement application** | **Governmental policy maker** | **User (individual or enterprise)** | **cell tower operator** | **wireless carrier** | **researcher** | **standards developer** | **User device vendor** | **Mobile Application developer** |
| Overall data on Quality of Experience of set of networks available to consumers | x | x | x | x | x |  | x | x |
| Quality of Experience of a specific network |  | x | x | x | x |  | x | x |
| Identify limitations in deployment of a specific network |  | x | x | x |  |  |  |  |
| Monitor for changes in operation of a specific network |  | x |  | x |  |  |  |  |
| Diagnose problems in a specific network |  |  | x | x |  |  |  |  |
| improve knowledge of system performance |  |  |  | x | x |  |  | x |
| lead the market toward more effective networks | x |  |  |  |  |  |  | x |
| encourage the redeployment of scarce spectrum using efficient technologies and implementations | x |  | x | x |  |  |  |  |
| compare measured performance data to simulated results |  |  |  |  | x | x |  |  |
| assess theoretical models |  |  |  |  | x | x |  |  |
| assess technology elements proposed during standards development |  |  |  |  |  | x |  |  |

Table 1: Assessment of key measurement applications per stakeholder role

# Mobile-Specific Considerations

The standard shall take into consideration the specific circumstances relevant to mobility and the resultant implications on measurements. In the mobile case:

1. measurements will typically be related to a specific user device, rather than to a router on a LAN
2. a single user device can typically operate with multiple disparate network technologies
3. a single user device may connect with multiple operators
4. a user device experiences widely varying signal and network conditions
5. due to variability, far larger statistical samples may be required to draw generalized conclusions
6. significantly more metadata (including, for example, location information) is required to characterize the scenario of a specific sample
7. it may be necessary to trigger testing based on a set of environmental circumstances, such as location, rather than relying upon scenarios such as LAN quiescence as a trigger
8. active testing may be relatively more constrained due to practical issues, including data plan limits and battery consumption
9. underlying software on many mobile devices is relatively closed, and underlying network data is often relatively difficult to access

# Architecture

## Architectural Reference Model

Figure 1 illustrates the architectural reference model. The reference model refers to five Functional Entities: Controller, Client, Server, Data Collector, and Network Parameter Host. The Functional Entities are described in more detail in subclause 6.3.

Note that the architectural reference model is similar to those described in other documents, such as [3], [4], and [5], but with a simplified set of communication links.



Figure 1: Architectural Reference Model (Private Entities Only)

## Expanded Architectural Reference Model showing Public and Private Entities

The expanded architectural reference model illustrated in Figure 2 indicates that the Measurement Client is able to communicate with two distinct forms of Measurement Server: Public and Private. Likewise, the Measurement Client is able to communicate with two distinct forms of Data Collector: Public and Private.



Figure 2: Application of Architectural Reference Model

Note that the Private Server and Private Data Collector do not register with the Controller and are unknown to it. Their identities need to be set by direct Client configuration and are not passed to the Controller. In effect, they are known only to the Client and to each other. In contrast the identities of public functional entities are known by the Controller.

The expanded architectural reference model, with additional functional entities, offers an additional set of implementation options that provide for a greater range of applications. For example, consider the Measurement Server:

* Some applications may prefer that the Measurement Server be publicly available. Such public accessibility allows the Measurement Server to provide a measurement termination point for experiments conducted by client devices belonging to general public consumers who have no access to a private Measurement Server. As a result, public Measurement Servers appear necessary to support large-scale consumer measurement campaigns.
* One limitation of a public Measurement Server is that the route to the server may not be representative of the traffic route of interest to the user. From the perspective of a large-scale consumer measurement campaign, that may not be a concern. However, from the perspective of a user, it could be a distinct weakness. In particular, some users may have a primary need for connectivity to a specific network; for example, an enterprise user may be most interested in connectivity to a corporate data server. In such cases, an appropriately-located private Measurement Server would best serve that user’s needs. A private Measurement Server could also provide additional advantages; for example, it could implement some custom measurement metrics of particular interest, and it could better protect the privacy of the user data.
* In the context of Figure 1, the Measurement Server could be public or private. However, it is possible to envision scenarios in which the functionality of the system would benefit from having both types of Measurement Server available to clients. For example, a large-scale consumer measurement campaign might have access to more data if it could convince enterprise users – those conducting measurements using a private Measurement Server – to conduct some measurements using a public Measurement Server as well.
* Note also that the public and private Measurement Servers may require different functionality. For example, the private Measurement Server may require additional authentication with respect to the Client. Also, as described in Figure 2, the public Measurement Server is provided with additional connectivity. It registers with the Controller, which allows a public Controller to select from a database of known public Measurement Servers, whereas a private Measurement Server might be known directly by the Client. Furthermore, Figure 2 indicates that the public Measurement Server submits measurement data to the Public Data Collector. For the purposes of large-scale consumer measurement campaigns, such data might be considered more reliable than data submitted by another entity. However, from the perspective of an enterprise user concerned with data privacy, such a data flow may be undesirable. However, the private Measurement Server might communicate date to the private Data Collector.

Note also a drawback to the use of the Public Server is that network operators could prioritize traffic to and from this server, which could result in measurements that inaccurately represent estimate the network performance experienced by users in practice. The use of a dual Measurement Server architecture could provide the opportunity for a check on such circumstances and could also allow controlled experiments to confirm.

These reasons help to motivate the inclusion of both Measurement Servers in the expanded architectural reference model. Likewise, we can consider the purpose of stipulating separate Public and Private Data Collector entities in the expanded architectural reference model as well. Clearly, large-scale consumer measurement campaigns require a public Data Collector, because the typical consumers lack another repository and because the campaign seeks to collect data from multiple Clients. The resulting data may be provided for public access. However, this results in a privacy dilemma. Since public users will be hesitant to volunteer for public data collection that potentially exposes their private information, it will be essential to ensure that collected public data is suitably anonymized. On the other hand, if the data is anonymous, it will not be of value to the individual users for analysis; the availability of such personalized data is the main incentive for the individual to participate in the campaign. The use of separate public and private Data Collectors provides an opportunity to resolve the dilemma. Professional or enterprise users, or any who wish to store data privately, are given the opportunity to do so, but opportunity is nevertheless provided for suitably anonymized data to be contributed to the large-scale campaign.

## Functional Entities

Table 1 specifies the Functional Entities of the Architectural Reference Model.

|  |  |  |
| --- | --- | --- |
| **Functional Entity** | **Type** | **Description** |
| Client |  | The Client is the central element of the Architectural Reference Model. It is typically embodied as software executing on the user edge device (the Client Device), typically a mobile terminal. The measurement process is intended to collect data representative of the performance of the network from the perspective of the user edge device. In the case of passive measurements, the Client will collect performance data characterizing communications to and from the Client Device. In the case of active measurements, the Client will initiate communications, for measurement purposes, with the Server. The Client posts resultant measurement data to one or more Data Collectors. In addition, the Public Server can submit experimental results to the Public Data Collector, using the address specified by the Client. |
| Controller |  | The Controller provides information to the Client governing the measurement process. This information includes the measurement triggers (which may include day/time information as well as other specific triggering details, such as location conditions). The Controller also provides the Client with the Server and Data Collector addresses. The Client registers with the Controller to indicate its address and availability to conduct measurements. It updates its registration status as needed.  Note: Inter-controller communications for configuration sharing may be specified. |
| Server | Public | The Server serves as a communication termination, providing a data source and data recipient for active measurements initiated by the Client. The Public Server registers with the Controller to indicate its address and availability to conduct measurements. It updates its registration status as needed. The address of the Public Server is specified to the Client by the Controller.  The results of measurements collected by a wide range of Clients using the Public Server should be readily comparable. Therefore, the characteristics of the Public Server should be well known and consistent, with minimal congestion and minimal variability.  The Public Server can submit experimental results to the Public Data Collector, using the address specified by the Client.  Note: A drawback to the use of the Public Server is that network operators could prioritize traffic to and from this server, which could result in measurements that inaccurately represent estimate the network performance experienced by users in practice. |
| Server | Private | The Server serves as a communication termination, providing a data source and data recipient for active measurements initiated by the Client. The Private Server is typically hosted in a network of primary interest to the user, so that measurement of communications between the Client and the Private Server are reflective of communications conducted by the Client device outside the measurement scenario.  The address of the Private Server is specified to the Client as a result of Client configuration controlled by the user.  Note: The tests conducted with the Private server need not be identical to those conducted with the Public server. |
| Data Collector | Public | The Data Collector receives measurement results from the Client. The Client transmits to the Public Data Collector only results that are intended for public use, with appropriate controls to prevent release of personally identifiable information (PII). In the case of active measurements, such data is limited to that collected from the Public Server. When a Private Data Collector is used, the Private Data Collector may forward public results to the Public Data Collector, in which case the Client need not be responsible for that transmission. |
| Data Collector | Private | The Data Collector receives measurement results from the Client. The Client transmits to the Private Data Collector results that are intended for private use only. When a a Public Collector option is selected by the Client, the Private Data Collector may forward anonymized public results to the Public Data Collector, in which case the Client need not be responsible for that transmission.  The address of the Private Data Collector is specified to the Client as a result of Client configuration controlled by the user. |
| Network Parameter Host |  | The Network Parameter Host is not used.  Note: The Network Parameter Host is included in the Architectural Reference Model for information only, since such a functional entity is described in other documents ([3],[4],[5]). Those documents are primarily oriented toward fixed networks. In those cases, this entity (also known as a “Network Information Subscription Server” or “Network Parameter Server”) stores information and provides such information about the “nominal” network performance, such as the nominal service characteristics as specified in a network subscription. Such information may be available to a network operator but is generally not publicly available, so accessing this information without violating privacy concerns is problematic. Also, in the mobile case, the active network access provider depends on circumstances; for example, the link may be to a wireless LAN or a roaming cellular provider, so that subscription information may be of little relevance. Furthermore, such information is of little value in the mobile environment generally, since performance is highly dependent on many environmental parameters that vary significantly with respect to nominal performance, and information about these environmental conditions can be obtained directly through observations collected by the Client. |

Table 2: Functional Entities

# Communication Links

## Summary of Communication Links

Table 2 summarizes the communication links among Functional Entities of the Architectural Reference Model.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| To=>  From⇓ | Client | Controller | Server-Public | Server-Private | Data Collector-Public | Data Collector-Private |
| Client | - | registration (including updates) | measurement execution  (initiator) | measurement execution  (initiator) | storage  (measured data and metadata, public) | storage  (measured data and metadata, public) |
| Controller | configuration  (schedules/  triggers)  (including updates) | configuration | - | - | - | - |
| Server-Public | measurement execution  (responder) | registration  (including updates) | - | - | storage  (measured data and metadata, public) | - |
| Server-Private | measurement execution  (responder) | - | - | - | - | - |
| Data Collector-Public | - | - | - | - | - | - |
| Data Collector-Private | - | - | - | - | - | - |

Table 3: Communication links among Functional Entities

# Data elements and messaging

## Client to Controller – Registration

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| tbd |  |  |
| [current network type] |  |  |

Table 4: Communication links: Client to Controller

## Public Server to Controller – Registration

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| tbd |  |  |
|  |  |  |

Table 5: Communication links: Public Server to Controller

## Controller to Client – Configuration

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| Server Address - Public | IP address or fully qualified domain name | path to Public Server |
| Collector Address - Public | IP address or fully qualified domain name | path to Public Data Collector |
| Configuration Expiry | hours | How often Client should check Controller for config changes |
| Data Usage Limit | kilobytes | The maximum number of bytes the Client will transfer in one month |
| Distance Threshold | meters | Land distance from previous test a Client must exceed to perform its next test set |
| Time Threshold | minutes | Time since previous test a Client must exceed to perform its next test set |
| Location Threshold | meters | Accuracy threshold above which Client will not initiate test set |
| Test Set | Array of integer | List of indexes of tests to conduct |
| Test Parameters | Array of string | List of test-specific parameters |
| Registration Interval | seconds | How often Client should re-register with Controller |
| [Re-registration trigger parameters] |  |  |
| Battery Threshold | percentage | The battery level below which the Client will not submit to Data Collector |
| [additional conditional triggering parameters] |  |  |

Table 6: Communication links: Controller to Client

## Controller to Controller – Configuration

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| tbd |  |  |
|  |  |  |

Table 7: Communication links: Controller to Controller

## Client to Public Server – Measurement Execution

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| tbd |  |  |
|  |  |  |

Table 8: Communication links: Client to Public Server

## Client to Private Server – Measurement Execution

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| tbd |  |  |
|  |  |  |

Table 9: Communication links: Client to Private Server

## Public Server to Client – Measurement Execution

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| tbd |  |  |
|  |  |  |

Table 10: Communication links: Public Server to Client

## Private Server to Client – Measurement Execution

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| tbd |  |  |
|  |  |  |

Table 11: Communication links: Private Server to Client

## Test Set measurement metadata

|  |
| --- |
| **Description** |
| Test Set measurement metadata elements |
| Note: Elements to be considered as public or private, subject to privacy policy review. |
| Public Server Identifier  Cellular carrier  Network type  Network technology  Network identifier  Base station identifier  Cell identifier  Cell location code  Network Mobile County Code  Network Mobile Network Code  Roaming state  Signal strength (RSSI)  Wi-Fi radio state  Wi-Fi connection state  Enterprise identifier  Latitude  Longitude  Altitude  Speed of travel  Direction of travel  Location Accuracy  Location data provider  SIM Mobile County Code  SIM Mobile Network Code  SIM provider  Power adapter state  Battery state  Battery charge level  Battery temperature  Battery voltage  Device unique identifier  Device manufacturer  Device brand  Device model  Device operating system type/version  BIOS Identifier  CPU information  CPU activity/load  Screen resolution  Free disk/RAM space  Free memory card storage space  Number of running apps |

Table 12: Test Set measurement metadata elements

## Client to Private Data Collector – Storage

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| Test Set – Public | Array of floating | Test Set measurement report - Public |
| Metadata Set – Public | Array of floating | Test Set measurement condition report – Public  *Note: Test Set measurement metadata elements, considered as public based on privacy policy review* |
| Test Set – Private | Array of floating | Test Set measurement report - Private |
| Metadata Set – Private | Array of floating | Test Set measurement condition report – Private  *Note: Test Set measurement metadata elements, considered as private based on privacy policy review* |

Table 13: Communication links: Client to Private Data Collector

## Client to Public Data Collector – Storage

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| Test Set – Public | Array of floating | Test Set measurement report |
| Metadata Set – Public | Array of floating | Test Set measurement condition report – Public  *Note: Test Set measurement metadata elements, considered as public based on privacy policy review.* |

*Note: The Public Data Collector could receive data from* *the* *Private Data Collector (per 8.14) rather than from the Client, obviating the need to duplicate over-the-air communication from the Client. Data propagating via the Private Data Collector might differ due to obfuscation techniques, etc.*

Table 14: Communication links: Client to Public Data Collector

## Public Server to Public Data Collector – Storage

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| Server Identifier |  | Unique identifier per server. |
| Experiment Identifier |  | Provides a record of each experiment, for later validation by correlation with Client Test Set measurement report. |
| tbd |  |  |

Table 15: Communication links: Public Server to Public Data Collector

## Private Server to Private Data Collector – Storage

This section is not applicable for the Mobile Application Developer use case, whereupon the Client communicates this information directly to the Private Data Collector.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| Server Identifier |  | Unique identifier per server. |
| Experiment Identifier |  | Provides a record of each experiment, for later validation by correlation with Client Test Set measurement report. |
| tbd |  |  |

Table 16: Communication links: Private Server to Private Data Collector

## Private Data Collector to Public Data Collector – Storage

If the user opts into the Public Data Collector, the anonymized data in this section is transmitted from the Private Data Collector to the Public Data Collector

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Type/Units** | **Description** |
| Test Set – Public | Array of floating | Test Set measurement report - Public |
| Metadata Set – Public | Array of floating | Test Set measurement condition report – Public  *Note: Test Set measurement metadata elements, considered as public based on privacy policy review.* |

Table 17: Communication links: Private Data Collector to Public Data Collector

# Considerations on privacy protection involving transmission of data from Private Data Collector to Public Data Collector

[tbd]

[location obfuscation, etc.?]

[usage guidelines?]

# Requirements

1. The standard shall specify procedures for characterizing and assessing the performance of deployed mobile broadband networks from a user perspective.
2. The standard shall specify metrics broadly applicable to all IP-based mobile broadband networks.
3. The standard should reference metrics specified by IETF (particularly from the IP Performance Metrics (IPPM) Working Group) whenever feasible.
4. The standard shall specify test procedures.
5. The standard shall specify procedures for a measurement server to collect information from a disparate set of user devices on the network.
6. The standard shall specify communication and data exchange protocols and data formats allowing a network-based server to coordinate and manage test operation and data collection.
7. The standard shall be implementable in software.
8. The standard should be compatible with implementation by any IP-based server in conjunction with any IP-based user device.
9. The standard should consider how to minimize (consistent with an overall optimized solution) the cost burden on the user device due to the extent that data transfer may be subject to a fee from the carrier, may interfere with other active user device processes, and may drain the user device power.
10. The standard shall specify procedures for measuring including uplink throughput rate, downlink throughput rate, latency, and jitter.
11. The standard shall specify procedures for quantifying packet loss and timeouts.
12. The standard shall specify procedures for collecting and transmitting various types of metadata, to include carrier network, network type, cell ID, user device make/model, network policy information, and radio resource control parameters, if available.
13. The standard shall specify procedures for collecting and transmitting user device location and location accuracy associated with measurement events.
14. The standard shall specify procedures for reducing user device location accuracy for privacy protection.
15. The standard shall specify procedures to ensure that Personally Identifiable Information (PII) is treated sensitively and protected from unauthorized disclosure.
16. The standard shall specify procedures to manage and respond to user consent authorization with regard to PII.
17. The standard shall specify anonymization procedures.
18. The standard shall provide for control of the tradeoff between cost and performance, so that cost-driven users can reduce the number of measurements and the thoroughness of measurements to obtain lower-cost operation, albeit with less complete information. The standard should recommend means of estimating and reporting the statistical validity of a set of measurement data.
19. The standard shall specify procedures based on active probing.
20. The standard should specify procedures based on passive measurements.
21. The standard shall support the needs of the public and research communities for collection of openly accessible anonymized data.
22. [addition requirements (tbd)]