Performance Measurement Definition

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ABSTRACT

Performance measurements within wireless telecommunications networks often fail to meet the needs of the diverse community of end users of those measurements. New features develop, networks evolve, and operating conditions change without sufficient consideration given to the measurements needed to keep the network running efficiently. While Development Engineering groups define measurements to satisfy their particular needs, other perspectives, especially the voice of the Network Operator, are often lost during the development process. What is lacking is a coherent methodology for defining performance measurements. This method needs to include meaningful criteria for choosing and rejecting potential sets of measurements, as well as keeping these measurements up to date.

In this paper Motorola describes a methodology to handle the above problems. In particular, multiple user communities have been defined representing the end users of system measurements. Performance goals and measurements are defined considering these same user communities. The definition includes identification of specific problem scenarios and corrective actions to be taken by the appropriate user community. Then, actual measurements are defined. Once implemented, performance goals and measurements are periodically evaluated for continued usefulness.

This performance measurement definition methodology has been institutionalized within Motorola's iDEN Technology Division. A performance measurement definition group composed of system developers and members of the other user communities has been established and is currently using the methodology.

1. Introduction

Performance measurements are important to the proper and efficient functioning of wireless telecommunications networks. They have numerous uses related to resource utilization, expansion planning, network optimization, operating problem diagnosis, and network availability monitoring. For the wireless telecommunications world product performance measurements are necessary to support multiple communities of users.

While most wireless telecommunications networks collect performance measurements, unfortunately, their use doesn't satisfy all communities of users equally. Motorola contends that: 1) the commonly used method for defining these performance measurements is flawed and 2) the content within the definition is inadequate.

This lack of completeness and correctness results in a host of problems ranging from Network Operator dissatisfaction through poor operating practices to substantial gaps in reporting appropriate data from the wireless telecommunications network.

In addition, once performance measurements are defined for a wireless telecommunication network they must be maintained. The evolution of a wireless telecommunication network for capacity increases and feature extensions leads to the evolution of the collected measurements. Performance measurements need to be added, modified, and obsoleted from the overall measurements repository. These changes must be defined completely and accurately to meet the requirements of each community of users.

A development of a performance measurement life cycle process to oversee this need was proposed. This life cycle requires tight coupling with the feature development process. The life cycle process addresses the multiple user communities whose perspectives are needed to supply the requirements for the performance measurements.

The proposed performance measurement life cycle process is a usage based process. The basic Goal, Question, Metric (GQM) method is enhanced to describe problem scenarios and corrective actions. These descriptions are not only used to filter out proposals for performance measurements that provide no defined benefit, but also support user community training in the use of the performance measurements. Finally, the performance measurement life cycle includes a managed change control process. It encompasses changes encountered for both the short-term, during definition and implementation, and the long-term.

The remainder of this paper is organized as follows.

- Section 2 defines performance measurements user communities for wireless telecommunications
- Section 3 describes the GQM and the Enhanced GQM methods
- Section 4 presents a generic process for performance measurements definition and maintenance and iDEN's specific process as a real-world example
- Section 5 discusses the status of institutionalization within iDEN
- Section 6 provides the conclusions

2. Measurements User Communities

The intent of Performance Management as a functional subset of operations and maintenance processes is to define a set of measurements. Typical definition criteria revolve around measuring activity within the network in terms of volume, speed, and accuracy. While this approach produces measurement data it does not completely address the needs and uses of the multiple consumers of network performance measurement information. Motorola proposes to extend the measurement definition criteria to better satisfy multiple groups with diverse needs for these measurements.

A qualitative judgement as to the efficacy of a Performance Management subsystem is how well served these different groups are by the measurements provided. To better understand these needs Motorola has defined five generic categories of users and outlined definitions and examples of their needs and requirements for measurements taken from their wireless telecommunications network. Motorola refers to these groups as measurements user communities.

1. Operator's Business Community
2. Operator's Maintenance Community
3. Operator's Traffic Engineering Community
4. Equipment Vendor's Performance Modeling Community
5. Equipment Vendor's Development Community

The first measurements user community is the Network Operator's Business Community. This community is defined under the assumption that the wireless telecommunications network is fully operational, adequately engineered for traffic load per quality of service definitions, and in commercial service. The primary objective of the Business Community is to guarantee the financial health and welfare of the Operating Company. They expect a properly configured wireless telecommunications network to supply the revenue per subscriber unit necessary to meet their financial goals.

An understanding of the elasticity of demand can help the Business Community maximize profits within their product pricing strategy as they alter prices according to various mixes of services. Typical measurements of interest to this community are those based on the actual volumes of calls completed by service type. This call volume information can lead to trends of usage over time. Correlation between price mix and call volumes can help to identify pricing strategies geared towards increasing revenue per subscriber unit.

A second measurements user community is the Network Operator's Maintenance Community. This community is defined under the assumption that the wireless telecommunications network is less than fully operational, adequately engineered for traffic load per quality of service definitions, and in commercial service. The primary objective of the Maintenance Community is to reduce Mean Time to Repair faults that occur within the fixed network equipment of the Operating Company.

The baseline metric for this community is the availability of the fixed network equipment, where availability is composed of the sum of scheduled and unscheduled outages to the fixed network equipment. Unscheduled outages are influenced by the inherent hardware and software quality of the products provided to the operating company. While the Maintenance Community has no direct control over that quality, they do have control over the second component of scheduled outage, Mean Time to Repair.

Mean Time to Repair is influenced by the Mean Time to Detect a fault. This community of user's defines measurements that support detecting or predicting faults within the fixed network equipment.

Measurements that support this community can come from places other than the fixed network equipment, itself. Several Operating Companies have been observed building information systems based on the data provided by Call Detail Records and Billing Records. Correlation is sought within these data between call faults and location within the Network. Detection of these faults serves a dual purpose: it allows the Operating Company a view of performance at the level of their Network Operator (the subscriber) and it allows the Maintenance Community to target specific fixed network equipment for repair.

A third measurements user community is the Network Operator's Traffic Engineering Community. This community is defined under the assumption that the wireless telecommunications network is fully operational, inadequately engineered for current or future traffic load per quality of service definitions, and in commercial service. The primary objective of the Traffic Engineering Community is to keep the capacity of the fixed network equipment within 1) the Operating

Company's design criteria for the quality of service based on growth of the subscriber base, 2) changes in usage patterns based on pricing strategies, and 3) introduction of new services.

The baseline metric for this community is the trend in utilization of the fixed network equipment. A fully instrumented network would allow the Operating Company to understand the trend in performance of their principle capital investment and any leased services. As these trends pass thresholds of performance, purchasing decisions or volume pricing discounts could be triggered.

A fourth measurements user community is Equipment Vendor's Performance Modeling Community. This community is defined under the assumption that the wireless telecommunications network is fully operational, adequately engineered for traffic load per quality of service definitions, and in some level of call capable service. The primary objective of the Performance Modeling Community is to guarantee that the models used during analysis and design conform to real-world observations of the fixed network equipment of the Operating Company.

While this community isn't within the Operating Company it still provides beneficial service to the Operating Company by managing the development of subsequent features that are in line with the actual performance characteristics of the network. Many decisions within the development life-cycle depend on models developed prior to shipping the product. These models need to be calibrated to network performance once the product is released. Definition of measurements in concert with calibrating these models requires the direct involvement of the people developing the models.

The network that transports Network Management data often is the same network that carries call control traffic. Clearly, the knowledge of volume levels of this traffic during anomalous operating conditions is important in order to understand the total impact to call processing. This community would define measurements to allow the monitoring of this phenomena.

A fifth measurements user community is Equipment Vendor's Development Engineering Community. This community is also defined under the assumption that the wireless telecommunications network is fully operational, adequately engineered for traffic load per quality of service or service level agreement definitions, and in commercial service. The primary objective of the Development Engineering Community is to guarantee that the implementations of the designs conform to real-world observations of the fixed network equipment of the Operating Company.

While this community also is not within the Operating Company, it still provides beneficial service to the Operating Company. The implementation of new algorithms carries some finite risk of performance in the Network Operator environment versus the lab environment. Many times simulators of network activity are developed to support the verification of these algorithms. These simulations need to be calibrated to network performance once the product is released. Definition of measurements in concert with calibrating these simulations requires the direct involvement of the people developing the simulations.

The five measurements communities are broken into three external Network Operator based groups and two internal Equipment Vendor groups. However, experience shows that the measurements defined for these groups are not mutually exclusive. Measurements needed by one group for one purpose can also be used by other groups for other purposes. Thus, the accurate definition of the measurements and how to use them is necessary to allow the Network Operator to properly combine these measurements into more complex analyses.

The iDEN implementation of the Performance Management subsystem allows the Network Operator access to measurements independent of the measurements community they were defined for. The measurements are viewed as low level data necessary to support the higher level functions of analysis and problem solving necessary to operate a wireless telecommunications network.

3. Enhanced GQM

The Goal, Question Metric (GQM) method requires measurements user communities to help define goals and metrics. This section first presents the standard GQM method, and then presents an enhanced GQM method which provides the measurements user communities a broader understanding of how metrics are used. Note that the term 'metric' in GQM means the same as 'measurement'.

3.1. GQM Methodology

The GQM method was originally proposed by Basili and Weiss [2]. This methodology provides a systematic approach for defining metrics which can be collected and analyzed to determine whether or not a goal has been reached. GQM is comprised of the following three steps.

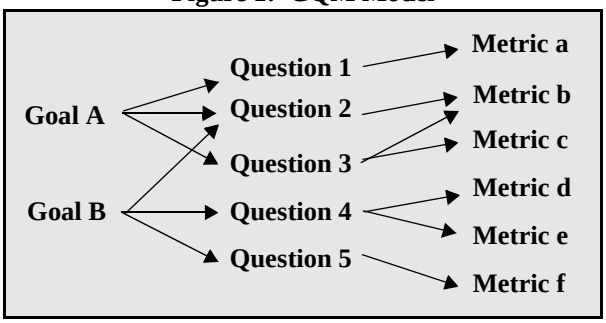
1. Identify and define goals for a particular group

2. Refine goals into quantifiable questions
3. Define metrics which will answer the questions

Goals are defined in terms of a purpose and a perspective. The purpose specifies the object to be analyzed and why it will be analyzed. The perspective specifies the relevant aspects of the object and which measurements user community is interested in the aspects.

Execution of the GQM methodology results in the formation of a GQM model. A GQM model contains the set of defined goals, questions, and metrics. A GQM model provides traceability from the goals to the associated metrics. Figure 1 shows an example of a GQM model.

Figure 1: GQM Model



GQM definition templates are often used to help produce consistent goal, question, and/or metric definitions. An example of a Goal template is [1]:

Purpose: To (characterize evaluate, predict, motivate, etc.) the (process product model, metric, etc.) in order to (understand, assess, manage, engineer, learn, improve, etc.) it. Example: To evaluate the system testing methodology in order to improve it.

Perspective: Examine the (cost, effectiveness, correctness, defects, changes, product metrics, reliability, etc.) from the point of view of the (developer, manager, Network Operator, corporate perspective, etc.). Example: Examine the effectiveness from the developer's point of view.

3.2. Enhanced GQM Methodology

As it stands, the GQM methodology works well for defining metrics, but falls short in several areas. In order to better fit performance measurement definition within the wireless telecommunications world the GQM methodology was enhanced for the following reasons.

- Allow measurements user communities to specify their needs at the beginning of the performance measurement life cycle rather than waiting for a product to be delivered
- Allow measurements user communities to understand what performance measurements are being designed for them in time to modify their reporting processes
- Allow measurements user communities to understand how they should analyze collected measurement data and what actions they should take when analysis has been completed
- Provide criteria for rejecting unnecessary goals, useless metrics, or metrics that can not be properly collected or computed
- Provide criteria for architecting metrics into the appropriate wireless network device (based on network traffic capacity, device CPU and memory capacity, network manager data collection capabilities, etc.)
- Provide enhanced GQM model definition and metric definition templates to produce consistent definitions

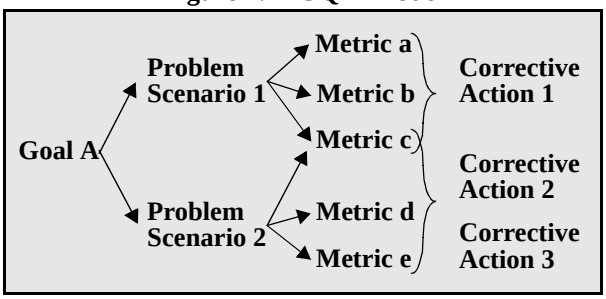
The Enhanced GQM, or EGQM, methodology is comprised of the following four steps.

1. Identify and define measurement goals for a particular measurements user community
2. Refine measurement goals into quantifiable problem scenarios
3. Define metrics which will determine if the goal is being accomplished
4. Define corrective actions

EGQM's first and third steps are similar to GQM's first and third steps. EGQM's second step is different than GQM's second step in that it focuses on problem scenarios associated with the goal rather than on questions associated with the goal. Problem scenarios are descriptions of real world problems the measurements user community has or will experience. Each problem scenario represents a particular aspect of the associated goal. Problem scenarios include definitions of any formulas that will allow the measurements user community to analyze the problem scenario after metric data has been collected from the field. EGQM's fourth step is new. Corrective actions are descriptions of what the measurements user community should do based on analysis of metric data collected from the resulting wireless network.

Execution of the EGQM methodology results in the formation of a EGQM model. A EGQM model contains the set of defined goal, problem scenarios, metrics, and corrective actions. A EGQM model also provides traceability from the goals to the associated corrective actions. Figure 2 shows an example of a EGQM model.

Figure 2: EGQM Model



EGQM has definition templates for producing a EGQM model and for defining metrics. The EGQM model definition template is shown in Table 1. The EGQM metric definition template is shown in Table 2. Note that the metric definition template contains iDEN specific definitions, but the definitions can easily be tailored to work for any wireless network.

Table 1: EGQM Model Definition Template

Goal: Provides the name of goal and non-ambiguous definition of what needs to be accomplished. Also provides the measurements user community the goal is associated with.

Problem Scenarios(s): Provides a description of the problem scenario associated with the goal. Contains a description of how performance measurements will be used by the user in order to meet the goal.

Required Metrics(s): Provides a list of metrics required to assess the problem scenario to see if the goal is being accomplished.

Corrective Actions(s): Provides descriptions of actions the user can execute based on data collected from the wireless network. Contains descriptions of expected metric data values and how those values work with the Problem Scenarios definitions.

Table 2: iDEN's EGQM Metric Definition Template

Collection Device Table: Table containing metrics for a given iDEN network device (ACG, APD, BRC, BSC, DAP, iDEN HLR, MDG, or OMC-R) that will collect the metric. The format is a table containing the fields described below.

Name: The name of the metric. The format of this field is text, abbreviations and acronyms should be used sparingly.

Description: A complete non-ambiguous definition of the metric including: description of metric, specific unit of measure, description of how device collecting the metric updates the metric. The format of this field is text.

Scope: A definition of the domain in which the metric applies and the maximum number of metric instances the device may collect. The format of this field is <domain> / <instances>. Examples of valid iDEN domains include: System, Location Area, Site, Cell, MDG, DAP, iDEN-HLR, (P|S)CCH, PCH.

Type: A definition of the metric type. The type helps determine the CPU utilization required to collect the metric. Together, the scope and type determine the amount of memory required to collect and store the metric. The format of this field is one of: Bucket, Counter, Counter-Cause, Distribution, Distribution-Cause, Duration, Gauge, Histogram, Link Outage, Number, Percent, or Range.

As described in Section 2, five measurements user communities have been defined for the wireless telecommunications industries. EGQM supports all five communities. Representatives from each community participate in all four steps of the EGQM methodology. This allows user communities to specify exactly what they need and/or want, and to know exactly how they will use the metrics before any code is developed. Participation in the EGQM process increases Network Operator satisfaction through early definition of operational practices (i.e., corrective actions) and increases product knowledge within the Network Operator organization.

The EGQM model definition and metric definition templates provide the mechanism to reject unnecessary goals, useless metrics, or metrics that can not be properly collected or computed. Reasons for the rejection of a goal include the following.

- Non-ambiguous goal definition could not be determined

- Problem scenarios could not be determined
- Definition of how performance measurement will be used within a problem scenario could not be determined
- Corrective actions could not be determined
- Metrics could not be defined to support problem scenario definitions
- Required metrics could not be architected into network devices for any of the following reasons
  - Network device could not collect metric due to CPU utilization issues
  - Network device could not collect and/or store metric due to memory issues
  - Network could not support the uploading of measurement data from network devices to network manager
  - Network manager could not collect and/or store measurement data due to memory issues

4. PM Process Definition

The EGQM method, with the use of performance measurements user communities, provides an excellent framework for defining performance goals and metrics. However, such a framework is not complete without a context, or process, in which to execute. This process is needed to define numerous things, such as when measurements are to be defined, who is to participate, how the work products fit into the development cycle, and how change is managed.

Such a process is described below, first generically, and then with examples drawn from the iDEN implementation. Included in this description is a specification of a life cycle for maintaining performance measurement goals and definitions, as well as a discussion of the group that bears much of the burden of defining performance measurements and managing the life cycle.

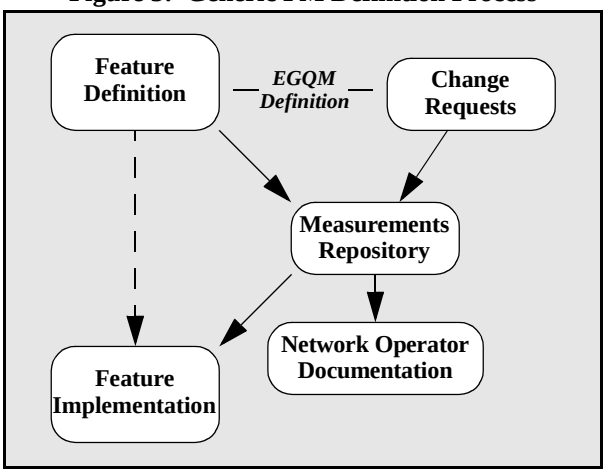
4.1. The Generic Process

The EGQM methodology for performance goals and metrics definition can be incorporated into almost any feature development process (waterfall, spiral, prototyping, etc.). For discussion here Motorola assumes there exists both feature definition and feature implementation activities, with EGQM definition taking place within the feature definition activities, and metrics implementation during feature implementation.

Also needed is a method for handling change requests. While modifications to new features may be incorporated into the feature definition and implementation processes, changes to EGQM information for existing performance measurements will typically require an additional mechanism. In particular, this change request mechanism is expected to be used to support the performance measurements life cycle.

EGQM information itself is stored in some form of permanent repository. Aggregating performance goal and metric definitions has a number of benefits. These include providing a single source for applying changes, as well as providing an efficient organization for study and review. One important additional benefit is the ability to generate Network Operator documentation on the definitions and use of performance measurements.

Figure 3: Generic PM Definition Process



The resulting process is shown in Figure 3. EGQM information from feature definitions and change requests are used to update the measurements repository, which in turn drives metrics implementation and production of Network Operator documentation. If EGQM information from feature definition is used to directly drive metrics implementation then care must be taken to keep the measurements repository, which is used both for measurements life cycle activities and Network Operator documentation, synchronized with the implementation.

Change requests must encompass both goal and metric definition, and may be accomplished through separate documentation, as shown in Figure 3, or through modifications to existing feature definition documents. In either case, new EGQM information is merged into the measurements repository. At some point during the product release cycle, the measurements repository is used to produce Network Operator documentation incorporating information for the latest features and changes. This release of documentation needs to be made early enough to allow the Network Operator and Equipment Vendor user communities sufficient time to incorporate modifications into their own tools and analyses.

One key point to notice is that the performance

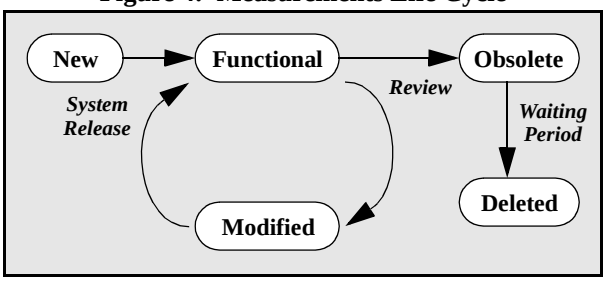
measurement definition process makes full use of existing feature development and change control processes. The major work is to incorporate the EGQM methodology itself into the development of the work products.

4.1.1 Measurements Life Cycle Process

If the uses of performance measurements were confined to features and occasional changes to those features, then the above process would suffice. However, user community needs evolve, operating conditions change, performance models are validated, and so on. As these conditions change so should performance measurements. Such considerations point to the need for a complete measurements life cycle model, with an appropriate process to manage it.

A simple life cycle model to handle performance measurement changes is depicted in Figure 4. New performance measurement goal and metric definitions are provided through new features. These are made available with system releases.

Figure 4: Measurements Life Cycle



Performance measurements are also periodically reviewed. Goal and metric definition updates made during this process are generally instantiated at system release. When metrics are no longer useful they are made obsolete, and eventually deleted. A waiting period between obsolescence and deletion allows user communities time to implement and test out new metrics and analyses that are meant to replace existing metrics and analyses.

4.1.2 PM Definition Group

Occasional performance measurement change requests to repair defects and introduce new functionality can be handled through existing procedures. However, the measurements life cycle process described above requires a more dedicated effort. In particular, a group specializing in performance measurement definition is needed to understand how conditions are changing, perform the periodic reviews, and ensure that the appropriate user communities understand and accept proposed changes. This group is called the Performance Measurement Definition group, or PM Definition group for short.

The PM Definition group operates primarily in a system engineering capacity. It is tasked with the following two responsibilities.

1. Define EGQM information for new features
2. Review / create change requests as part of the life cycle process to determine necessary EGQM additions, deletions, and modifications

Membership in the PM Definition group needs to cover the five user communities defined earlier and can be drawn from Equipment Vendor development and support organizations, as well as from Network Operators. A list of groups expected to at least provide input, if not actual members, would include the following.

- Network Operator
- System Engineering
- Performance Modeling
- Development Groups
- Operations
- Business Team

4.2. The iDEN Process

The performance measurement definition process, as implemented in Motorola's iDEN Technology Division, is shown in Figure 5. Feature definition contains two phases, with system requirements used to drive system architecture. The change request process is handled by a System Engineering Change Control Board. The PM Definition group serves as an adjunct to this board to both author and review performance related change requests. Taken together system requirements, system architecture, and change requests are used to drive product development.

In feature definition, goals are defined as system requirements. Comments are provided in addition to numbered requirements in which problem scenarios may be described. The system architecture phase completes the EGQM information by refining the problem scenarios and adding corrective actions and detailed metric definitions.

The similarity between the generic and iDEN processes is important. Both rely on the processes that already exist for feature definition and change requests. This means that process changes are restricted primarily to the definition of PM group activities, documentation templates, and a few interworkings.

Figure 5: iDEN PM Definition Process

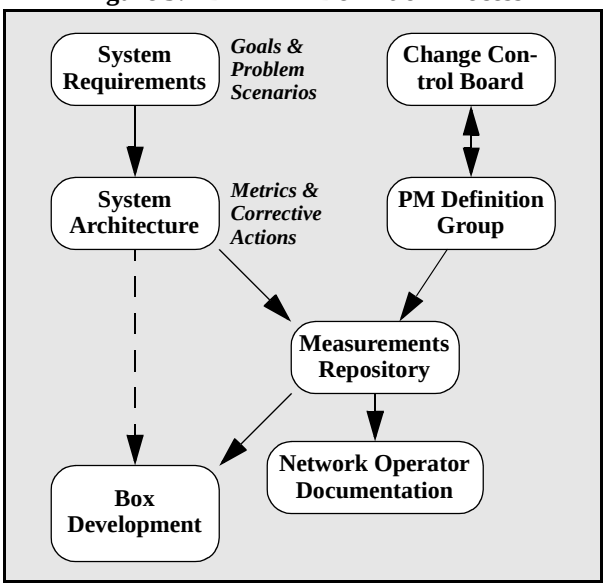


Figure 5 shows how the PM Definition group interacts with the change request process, and iDEN process documentation addresses this issue by providing details. The reason for specifying these relationships is that the PM Definition group has primary responsibility for introducing performance measurement change requests. A significant number of these requests are expected to be generated from user community inputs and life cycle reviews of legacy metrics and existing EGQM information. Thus, this process will be directly carried out by the PM Definition group, as a group.

However, the figure does not directly address the second responsibility of that group, namely, EGQM definition for new features. The rational for this decision is two-fold. First the iDEN process specifies performance measurement definition templates to be used in the system requirements and system architecture phases of feature definition. Second the PM Definition group is composed of many system engineers, whose responsibilities include performance measurement definition for their domains.

5. Status and Future Directions

Motorola's iDEN Technology Division has been using the EGQM method and user communities to define performance measures in a standardized format for the past eight system releases. These methods have proved invaluable to the definition process, especially for broadening its scope to include all users of performance measurements.

More recently, reviews for change requests are handled through PM Definition group participation, with input solicited from various user communities, including direct input from the Network Operator on occasion. EGQM definition for new features has moved from a separate PM Definition group to system requirements and architecture documents, with the use of pre-defined templates.

However, there remain several efforts that need to be initiated. These include the following.

- Automated production of Network Operator documentation from the performance measurement repository
- Start of PM Definition group life cycle reviews of legacy performance metrics and backfill to add full EGQM information
- Continued broadening of user community input into the performance measurements definition process

6. Conclusion

In the past, definition of performance measurements of wireless telecommunications networks was focused mainly on satisfying the needs of the Equipment Vendor Performance Modeling and Development Engineering measurements user communities. The needs of the wireless telecommunications Network Operator are not always addressed. The Performance Measurement Definition process described in this paper addresses the needs of all measurements user communities. The process also provides additional benefits, including the following.

- Allows measurement communities to specify their needs up front
- Allows measurement communities to prepare for and modify their measurement monitoring and reporting processes before product is released to them
- Allows measurement communities to know what actions they need to perform when assessing collected measurements
- Provides method for rejecting unrealistic goals and measurements
- Provides method for best architecting measurements into network devices
- Provides method for producing consistent measurement definitions
- Provides method for managing measurements life cycle including measurement creation, modification, and obsoletion

The Performance Measurement Definition process is relatively simple. Due to this simplicity, the process can be easily incorporated into any system requirement and system architecture life cycle methodology.

7. References

[1] Victor R Basili and H. Dieter Rombach, “The TAME project: Towards improvement-oriented software environments”, IEEE Transactions of Software Engineering, Vol. 14, No. 6, June 1988

[2] Victor R Basili and David M. Weiss, “A Methodology for Collecting Valid Software Engineering Data”, IEEE Transactions of Software Engineering, Vol. SE-10, No. 6, November 1984