# Communication model for $M^3$ – Open Multi-commodity Market Data Model

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**Abstract:** The Open Multi-commodity Market data Model (abbrev. $M^3$) may be used in designing open information systems for market balancing and clearing in the context of multi-commodity trade in various network infrastructure sectors. The primary requirement of the $M^3$ model is an easy exchange of all data between various market entities and market balancing processes. In this paper we address communication design issues of $M^3$ model and formulate robust basis of the communication model.

**Keywords:** multi-commodity trade, market clearing, open information systems, XML, SOAP

## 1. Introduction

At present, in many network industries, functionality and efficiency of the existing control and management designs are not completely satisfactory. During the past decades, the world-wide market liberalization and deregulation processes are being implemented in many network infrastructure sectors, including power systems, telecommunication, computer, rail and transport networks, water, urban systems and others.

Many researchers and professionalists around the world participate in development, investigation and implementation of a variety of new ideas related to auction and market clearing systems under various market conditions. In the network systems, an efficient market balance may be obtained in a single balancing process by joint optimization of trade of many elementary commodities and services related to buy and sell offers of the network resources. For this purpose the multi-commodity exchanges can be used, in addition to single-commodity exchanges and bilateral trading. The basic multi-commodity market clearing models are in the LP or MILP forms (see Toczylowski, 2002).

Apart from traditional auctions, long-term and medium-term single-commodity market segments, or day-ahead and intra-day-markets, there is a need for designing specific problem-oriented multi-commodity auctions and balancing market mechanisms, which must provide feasible execution of sales contracts and assure timely delivery of many goods and services.

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The market processes consist of of many elementary balancing and clearing processes. Usually, each process has its own mechanism for information interchange and processing. At present, there are no general world-wide standards for information interchange. In some industries however exist local standards for data interchange, e.g., RosettaNet in electronic industry, MDDL in financial sector and other standards specified on the basis of open standards like ebXML or XBRL (see $M^3$ Project Web page, Report). However, these standards are focused on business and financial data only, like invoices, offers, information concerning business partners, and so on.

Recently, the ontology-based languages (OWL, RDF) are used for definition of different types of systems, also turnover systems. However, for reason of their high complication level, this languages are not used in $M^3$ project. Integration with these languages is considered, by means of transformation from $M^3$ XML files to OWL and RDF form.

In our previous research (see $M^3$ Project Web page, and Kacprzak et al, 2007) we have initiated the design of the Open Multi-commodity Market data Model, abbrev. $M^3$ ) that may be used in designing information systems for market balancing and clearing in the context of multi-commodity trade in various network infrastructure sectors. In this paper we address the generic communication design issues of $M^3$ .

One purpose of the open $M^3$ model is that it creates a flexible framework for development of new market models and algorithms, benchmark data repository, and gives possibility for integration of software components which implement balancing mechanisms. Finally, it will help the community to determine the best industrial standards of data interchange and enable for an easy public access and exchange of various market data.

The multi-commodity market data interchange model consists of several layers: formal mathematical model (see $M^3$ Project Web page, and Toczylowski, 2002), conceptual data model, expressed in form of UML class diagrams (see Kacprzak et al, 2007), generic relational database structure, XML schemas for static data, communication models, XML schemas for messages, and Web Services definitions.

The paper is organized as follows. Section 2 presents briefly the basics of the $M^3$ model with some possible applications, section 3 describes the XML communication structures of $M^3$ model, topologies of communication, and message passing with XML messages. In section 4 the message flows are analyzed for some market processes.

## 2. Brief description of static data model

The key parts of the static data model for market balancing are: infrastructure, market entities structure, time structure, commodities, programmes, offers, commodities' balances and market prices.

Trading physical commodities (e.g. electrical energy) between the market participants requires a technical infrastructure to assure feasible delivery of services and goods. During the balancing process, the infrastructure plays the role of a system of limited resources, and is a medium for delivery of commodities and services. Infrastructure is modeled as a set of graphs $N$, where $n$-th graph is defined by $\langle V^n, E^n, P^{V^n}, P^{E^n}\rangle$, $n \in N$ is an index of network model, $V^n$ is a set of nodes, $E^n$ is a set of edges, $P^{V^n}$ and $P^{E^n}$ are parameters of vertices and arcs respectively. Infrastructure graphs constitute a hierarchy where the upper level infrastructure network, called virtual network, is an aggregation of a lower level graph. The most detailed network model is called basic network. Many aggregation schemas exist in parallel (see M$^3$ Project Web page, report).

Each balancing process is related to a time structure. Commodities are to be delivered in determined time slots. Thus the time horizon must be divided into time segments and every commodity is related to a time slot. The time structure is modeled as a directed acyclic graph $C = \langle V^C, E^C\rangle$, where vertices $V^C$ define time slots, and edges describe aggregation between time slots. Time structure includes basic time slots, e.g. hours. By aggregations of time slots one may form more sophisticated slots, e.g. load peak hours or days of week.

Market entities structure describes market players and relations between them. Again, it is modeled as a directed acyclic graph. Market entities form a hierarchy, where a given market entity may be composed of some other market entities, e.g. power plant may have several generation units. Market entities are related to infrastructure vertices. This relation has different semantic, depending on relation type, e.g. *is located*, *can deliver commodities*.

Commodity $c$ is described by the set $\langle t, v, e, d, P^t\rangle$, where $t \in T$, $T$ denotes the set of commodities' kinds that are specific for a given balancing process, $v \in V^n$, $e \in E^n$, $n \in N$, $d \in C$. Commodity can be related to node $v$ or to oriented edge $e$ from infrastructure model $n$. Parameter $d$ is a time slot from time structure $C$. $P^t$ describes the set of parameters for commodity types $t$, e.g. realization date for options. Each market commodity has current schedule of commodities' delivery which is called programme.

Data model M$^3$ provides three types of offers: simple, integrated and grouping offers. Simple offer is described by admissible range of commodity volumes and a unit price. Integrated offer is a typical type of offer for multi-commodity turnover, where players trade with packages (or bundles) of commodities with fixed proportions of commodities in the offer. The most complex type of offers are grouping offers. Grouping offer aggregate a set of other simple or integrated offers and describes relation between these offers. Grouping offers allow the market entities to define individual constraints.

For each elementary commodity $c$ traded during the balancing process, the conditions of balance are defined by pair $\{b_c^{min}, b_c^{max}\}$, which means that the difference between aggregated supply of commodity $c$ and the aggregated demand must be in a range of $\langle b_c^{min}, b_c^{max}\rangle$.

Major results coming form balancing process are market prices. Market prices are defined for each commodity $c$ as a couple: buy price $\pi_c^B$ and sell price $\pi_c^S$.

### 2.1. Possible $M^3$ applications

Proposed Open Multi-commodity Market Data Model may find many practical applications in industry and various market systems, as well as in research projects. Among other applications, $M^3$ may be used in a range of auction systems including traditional single-commodity auctions and more sophisticated combinatorial and multi-commodity auctions, e.g. Air-waves Auctions and Takeover Battles (Klemperer, 1998), or auctions of trackage rights (Caplice and Sheffi, 2003). $M^3$ allows to represent all necessary knowledge about market processes, entities, status, commodities, offers and auction results.

$M^3$ may be also very useful in many kinds of distributed infrastructure markets, such as: power (Baldick et al, 2005), telecommunication (Courcoubetis, 2003), and transportation systems (Borndorfer et al, 2005, Caplice and Sheffi, 2003), where exchange and delivery of commodities require some infrastructure, that limits the freedom of trade. During balancing processes, apart from data necessary in traditional markets, the system operator needs large amount of data concerning technical constraints. These information may be quite sophisticated, heterogeneous and distributed among various entities, therefore appropriate and efficient modeling is very important in such a case. In most of distributed infrastructure markets multi-commodity trade, naturally reinforced by $M^3$ , may solve many problems and improve market properties, like, e.g., joint trade of power, options, and transmission rights.

Many complex market systems are organized as a multi-stage markets. There are a number of consecutive balancing processes, which must cooperate, in order to balance the whole market. $M^3$ may significantly facilitate communication and coordination procedures by supplying universal, complete and flexible model to exchange data between all market processes and between market entities. Some kinds of multi-stage markets (*intra day* and *real-time markets*, see Smolira, Kaleta, Toczyłowski, 2006) requires relatively short repetition interval (e.g. 5 or 15 minutes). This entails big frequency of data exchange processes between market entities as well as between various balancing processes. Using $M^3$ may allow to automate bidding processes as well to increase whole communication frequency, ensuring possibility of sending all necessary data.

$M^3$ may be also very useful during research and experiments. Universal market data model may facilitate test environment creation, especially in case of complicated systems that consist of many different modules. What is even more important, $M^3$ may allow the designers to compare results achieved in various experiments, which use different environments, and are performed by different teams. At the moment, these comparisons are difficult due to heterogeneous and diverse environments, where every system uses specific specialized data model.

### 2.2. Simple example

In case of infrastructure markets[2] commodities are defined in context of network, so the description of network is in the core of $M^3$ data model. Let us focus on

[2] Such as liberalized electricity markets, access to railroads, etc.

example[3] of the electric energy trade on energy market. A simple transmission network is shown in Fig. 1. The whole network area is sliced into two zones. In this example we consider only a single basic network. However, it may be also considered as a virtual network formulated from a more detailed basic network, as shown in Fig. 1.

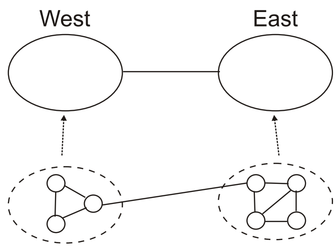


Figure 1. Simple transmission network

```
<m3:Network>
  <m3:name>
    Simple electricity transmission network with 2 nodes
  </m3:name>
  <m3:node id="ex:west" dref="ex:Zone">
    <m3:name>West zone</m3:name>
  </m3:node>
  <m3:node id="ex:east" dref="ex:Zone">
    <m3:name>East zone</m3:name>
  </m3:node>
  <m3:arc id="ex:east-west-connection" dref="ex:AggregatedLine">
    <m3:parameter dref="ArcCapacity">300</m3:parameter>
    <m3:predecessor ref="ex:east"/>
    <m3:successor ref="ex:west"/>
  </m3:arc>
</m3:Network>
```

For each network it is possible to provide some additional parameters that represent resource and technical requirements. These parameters depend on type of market and type of nodes or arcs, such as speed limit for sections of tracks in railroad market (see Borndörfer et al, 2005) or maximum power flow on particular transmission network arcs. Network parameters are defined in a separate XML File.

There may be many commodities associated with each network. Each commodity can be associated with some node (like electric energy in zones) or with some arc (already mentioned railroads). Below there is the definition of commodity that is the electric energy that should be delivered in node `east`.

[3] For the sake of space limitation in the paper we provide only snippets of XML files. Full example is available on $M^3$ Project Web page, appendix.

```
<m3:Commodity id="ex:el-e-070511-12" dref="op:ElectricEnergy"
  minBalance="0" maxBalance="0">
  <m3:description>
    Electricity at east zone on 2007-05-11 12:00-13:00
  </m3:description>
  <m3:availableAt ref="ex:east"/>
  <m3:CalendarScheduledCommodity ref="op:H07051112"/>
</m3:Commodity>
```

Time frame of delivery is defined in the Calendar – other part of $M^3$ .

$M^3$ allows for different offers – from the simplest elementary offers, to more complicated integrated/bundle offers and grouping offers (see $M^3$ Project Web page, report). In this case we consider elementary offers, which are made for one commodity. Here is an example of such offer:

```
<m3:Offer id="ex:o23787-92" offeredPrice="120.00">
  <m3:offeredBy ref="ex:west-generator"/>
  <m3:volumeRange minValue="0" maxValue="150"/>
  <m3:ElementaryOffer>
    <m3:offeredCommodity shareFactor="1" ref="ex:el-w-070511-12"/>
  </m3:ElementaryOffer>
</m3:Offer>
```

In this offer the market entity, referred as the `ex:west-generator`, offers to sell up to 150 MWh of commodity `el-w-070511-12`. Share factor of “1” indicates willingness to sell, share factor of “-1” indicates willingness to buy. Positive prices are used for money that market participant is obliged to paid or he demands to receive.

It is possible to submit offers for bundles of commodities. Commodities will be sold in constant proportion determined by share factors.

```
<m3:Offer id="ex:o23565-78" offeredPrice="230.00">
  <m3:description>Exemplary bundled offer</m3:description>
  <m3:offeredBy ref="ex:east-generator"/>
  <m3:volumeRange minValue="100" maxValue="200"/>
  <m3:BundledOffer>
    <m3:offeredCommodity shareFactor="1" ref="ex:el-e-070511-12"/>
    <m3:offeredCommodity shareFactor="0.5" ref="ex:el-e-070511-13"/>
  </m3:BundledOffer>
</m3:Offer>
```

In this case market participant will sell twice as much of commodity `el-e-070511-12` as of commodity `el-e-070511-13`. He will sell nothing or at least 100 and no more than 200 units of commodity `el-e-070511-12`.

# 3. Communication model

## 3.1. M$^3$ data model and XML schemas

As we already noticed, M$^3$ data model consists of several components: formal mathematical model, conceptual data model with UML class diagrams, exemplary relational database structure, XML schemas for static data, communication models, XML schemas for messages, and Web Services definitions. Here we describe in more details communication issues of M$^3$ .

All XML structures are defined using W3C XML Schema. XML structures for static data cover whole data model (see M$^3$ project Web page), and are designed mainly for data interchange between scientists and developers, who develop and test algorithms for balancing and optimizing turnover on multi-commodity markets. These structures may also be used – instead of a database – to store market data; that is why we call them 'static'.

## 3.2. Topologies and message passing

M$^3$ supports two topologies of communication on the market.

- Centralized, where market participants communicate with one central entity, e.g. balancing operator. In this model, direct data interchange between participants is of course possible, but it is not covered by M$^3$ messages.
- Distributed, where no central unit exists, and market participants directly communicate with each other using M$^3$ messages[4].

There exist, with respect to changeability, two categories of data. Current data, like offers, programmes, etc., describe temporary market state. Metadata define static objects appearing on the market, along with their identifiers; commodity kinds, market entities, networks, calendar, etc., belong to this category.

In both topologies, two models of message passing exist.

- Directional – message is sent to one recipient or a group of (explicitly listed) recipients. This is a proper model for passing current market data, e.g. submitting offers, and for registering changes in metadata, e.g. introducing new entities or commodities to the central repository. In this model, each request should be individually replied. This communication model can be modeled through a Simple Object Access Protocol.
- Broadcast – message is published to the public or to some group of entities (not explicitly listed). This model is appropriate for publishing market metadata, e.g. directories of market participants, catalogues of commodities known to the system, and for publishing results of balancing/optimization processes. This type of communication could be modeled on a few different

[4] Though both topologies are supported, this paper deals with centralized communication only.

methods. One of the methods is placing messages in some public repository (e.g. on public Web site), where every interested entity could withdraw them. The other considered way is constant polling a server (market operator) by some client, more precisely by a software agent. The polling could be performed through SOAP protocol.

Messages designed for $M^3$ communication can be interchanged by any means, like ftp, e-mail, etc., but are especially suitable for use with SOAP. In the centralized topology, a request-response communication can be used, with a market participant being an active, and a central unit – a passive party. A set of SOAP-based Web services should be available at the central unit, which implements necessary directional message passing and publishing services.

### 3.3. XML Messages

XML messages, used in communication on the market, are composed of the same elements and types as used in the static data model. Messages schemas import necessary simple and complex types definitions, and global element declarations from static data schemas, and enclose them with an envelope containing communication details. Each message contains only those parts of static structures, which are necessary in particular data exchange process the message is designed for.

$M^3$ message envelope contains identifier of sender/publisher (see details below), identifier of the recipient, date and time of sending/publishing, identifier of the message, expiry date and time. If the message is generated as a response to another message, called request, its $M^3$ envelope contains also message identifier of the request, a response status (e.g. error number), and error messages (in case of error).

In $M^3$ XML structures, all identifiers of all objects are defined as QNames, within a namespace owned by an entity (market participant, balancing unit, system operator, etc.) the object is defined by. In case of message passing, identifiers of the sender and of the message itself will probably belong to the namespace owned by the sender or its superior entity, and an identifier of the recipient – to the namespace owned by recipient or its superior unit. An identifier of the message is any sender-specific (i.e. unique in sender namespace) string, usually generated by the sender; it can be simply a message sequential number. It is used in replies to facilitate control of the messages sequence.

In SOAP-based communication, whole $M^3$ message is enclosed with SOAP envelope. SOAP `<fault>` element is used to describe communication and formal errors only (e.g. document not well-defined, request for unknown service), while $M^3$ envelope elements are used when a content-related error occurs (e.g. lack of necessary information, internal contradiction in the message, reference to an unknown identifier, disagreement between the message content and the knowledge owned by the recipient).

### 3.4. Security issues

In this early version of $M^3$ we do not deliver solutions related to security of the message flow. Messages are intended to be either intentionally non-secure, or passed in some secure environment, e.g. VPN. It is however possible, that in future versions of $M^3$ some security issues will be addressed.

## 4. Messages flow in $M^3$

The primary requirement of the $M^3$ model is an easy exchange of all data represented in the model between various market entities and market balancing processes. Therefore, a standard communication model, which should enable this, have to be defined. Typically system operator has to collect various data from market entities and other sources (offers, constraints, technical parameters, etc.), process them and send back the results. To assure correct work of some market balancing processes, we need to guarantee, that the market operator should immediately know about every submitted buy or sell offer. The participants also should instantly know about the current state of the market. $M^3$ messages may be also used to transfer data between various processes that take place during market balancing. Market operator may use them to send data between consecutive repetitive balancing processes, as well as between various market segments, and even between various elementary modules of a single balancing process (e.g. balancing module and constraint module). In the case of distributed market processes, the market entities may use some kind of a server for efficient exchange of data bilaterally.

### 4.1. Message flow example

In $M^3$ a key issue is appropriate communication between some market entities. To illustrate messages flow, we continue Example from section 2.2.

Let us assume existence of some market instance, with one market operator and two sellers (see Fig. 2). The message flow is the following:

**Tbe market operator registers his service in a public repository** To activate the market instance, the market operator should register his services in some central repository, using for example WSDL language.

**The market entities announce to participate in the market instance** Each of them should send a message to operator, which contains all required information about the market participant. This information is specified in MarketEntity object. The operator receives those messages, analyzes them and sends back an answer through the same message channel.

**Market operator publishes all needed information** The operator should assure that the needed information would be accessible, that is the Calendar object, Basic Network structure and a Dictionary object (see Kacprzak et al, 2007) should exist. Every participant of market, can receive those structures by calling message `Dictionary data request` (see Fig. 2a). In response, the market operator is sending all requested structures.

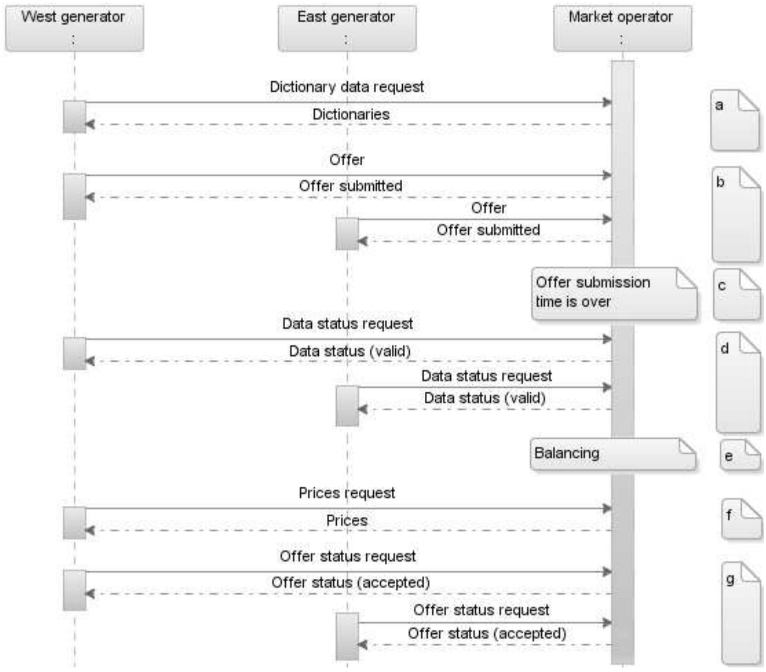


Figure 2. Sequence diagram for balancing market, with individual stages distinguished

**Market participant submits an offers** After market entity is successfully registered, it can submit offers. In this process the market participant should send a message with information concerning Offer and possibly Commodities for sell or buy, and sometimes some additional information. The additional information could be, for example, a more specific information about commodities (for massive-multi-commodity auctions/markets where every commodity is unique – for example Allegro or eBay auction services). Let us focus on power generator from West zone – the West Generator. To submit an offer a message, named `Offer`, has to be send to market operator. The message should contain his offer (see section 4.2). The market operator should tentatively analyze given offer and send back the answer: if the offer is correct or not (see Fig. 2b).

**Market paricipant checks if its offers were correctly formulated** After the submission process (see Fig. 2c), the market participants could check if their offers are correctly read; it is done by sending a message `Data status request`. In response, the market operator sends an answer, which contains a status report for given offer (see Fig. 2d).

**Market participant requests for its offers statuses and prices** After the balancing process (see Fig. 2e), which can be processed only once (e.g., some specific Vickrey auction, see Vickrey, 1961, Klemperer, 2004) or every specified time period (e.g., day-ahead market, see Toczyłowski, 2002) or after new buying or selling offer arrival (e.g., cry auction, see Klemperer, 2004), the market participants can send a `Price request` message to get information about prices (see Fig. 2f).

Every market participant can also check status of its offer, i.e. if it is accepted or rejected, prices for every commodity included in offers or prices for offers (for some multi-commodity markets e.g., Vickrey-Clarke-Groves mechanism, see Clarke, 1971, Groves, 1973). It can be done by sending `Offer status request` message. In response, the market operator sends `Offer status` (see Fig. 2g).

### 4.2. XML structure of messages

As it was stated before, the messages should be written in XML-based language. To illustrate structure of the message, we continue Example from section 4.1.

Let us assume, that the East Generator is going to submit an integrated offer. To do this he should, as it was described above, send a message `Offer` to the market operator. A fragment of such message is shown below:

```
<m3:Offer id="ex:o23565-78" offeredPrice="230.00">
  <m3:description>Exemplary bundled offer</m3:description>
  <m3:offeredBy ref="ex:east-genetator"/>
  <m3:volumeRange minValue="0" maxValue="0"/>
  <m3:volumeRange minValue="100" maxValue="200"/>
  <m3:BundledOffer>
    <m3:offeredCommodity shareFactor="1" ref="ex:el-e-070511-12"/>
    <m3:offeredCommodity shareFactor="0.5" ref="ex:el-e-070511-13"/>
  </m3:BundledOffer>
</m3:Offer>
```

The envelope of the message, with content described in section 3.3, was omitted for simplicity. As we can observe, the main part of the message contains a part of static data, namely `m3:Offer`.

## 5. Summary

The open multi-commodity market data $M^3$ model may be used in a wide range of market-oriented network systems and may significantly facilitate communication, coordination and modelling procedures, both from the market operators and market entities point of view. $M^3$ provides a set of formal data models, which results in XML-derived information interchange specification. The proposed communication structures of $M^3$ model may enable cooperation and easy data exchange between different market entities and market processes.

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