Opportunities for Implementation Machine-to-Machine Services via 3G Mobile Networks

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Abstract—Wireless machine-to-machine (M2M) communications are the new segment of cellular mobile communications, which gain a higher importance with emerging of 3G mobile networks. By the analysis of possible wireless M2M applications, 3G M2M applications are identified, as well as their possible market segments and target objects. On the basis of proposed penetration growth model and criteria for Croatian market requirements, penetration of traffic intensive and traffic non-intensive 3G M2M end-points are estimated.

Keywords-3G mobile; M2M; penetration forecasting

I. INTRODUCTION

Machine-to-Machine (M2M) communications covers applications in which data are used to create a link between systems, remote devices or locations and individuals [1].

Conventional platform for M2M services are fixed switching and data networks, as well as leased lines. In contrast to fixed networks, wireless M2M enable the connectivity, any time, any place. Some powerful steps have been recently made in commercial use of wireless M2M services, that utilize 2G and 2.5G cellular mobile networks as communication platforms [2]. This kind of wireless M2M, implemented in world-wide mobile networks, allows a wide variety of devices to be connected.

This is the next step in the evolution of communications extending connectivity beyond human beings, because it is not only people that use telecommunications networks to communicate, but the machines as well. M2M could be an attractive option in saturated voice markets: by using cellular mobile networks, new revenue opportunities can be created for mobile operators and terminal suppliers, without the need for expensive new investments [3].

II. WIRELESS M2M APPLICATIONS

Wireless M2M communications could cover full variety of applications from sales & payments, home and industrial applications to telematics / in-vehicle and telemedicine. New wireless M2M applications are continuously emerging, and they may serve almost any business area and physical environment.

Cellular mobile networks offer different network technologies for M2M communications (Fig. 1.), and there are strong optimistic predictions that wireless M2M over cellular mobile networks could be a leverage to provide much-needed mobile operator revenue.

![Wireless M2M](image)

Figure 1. Wireless M2M communications - a classification according to network generations

Some important issues about M2M via cellular networks are:
- The M2M market will also be global with no boundaries.
- Quality of service is a key parameter in M2M and it is essential for developing customer loyalty.
- M2M could be a useful tool in retaining existing mobile customers, creating loyalty, and increasing traffic by developing new data-based applications. [4]

Depending on the complexity or type of M2M application, one particular application could use several technologies to perform different tasks, the choice depending on the type and speed of data transfer required. The five network platforms present today and in the near future for M2M applications are: DTMF based services, SMS, GPRS, WAP-IP and 3G.

Nowadays, the majority of wireless M2M applications are based on SMS services. But, the always-on networks will be a key landmark in the development of M2M. They will enable the development of more specialized services with associated tariffs. This will be particularly true as the high-speed,
always-on networks become available. IP based services enable access to a whole range of mobile Internet and other data services. The broader bandwidth capability will open up new M2M applications in, for example, telemedicine [4].

The third generation of mobile networks removes some bandwidth and communications protocols limitations of previous generations of cellular networks and provides new opportunities for M2M communications. For instance, the requirements of the ETSI standards committee for reception in moving vehicles demand 3G UMTS transfer rates of at least 384 Kbps at speeds of 120 km/h in urban environments and 2 Mbps at speeds of up to 10 km/h.

Rather than the voice-centric environment, that has dominated the mobile world to date, 3G is an always-on data environment. Enabling reliable connectivity any time, any place to content, will clearly be an important role for 3G. Besides, 3G cellular mobile networks will take M2M to a higher level providing that to all machines and network equipment will conform to the same communications protocols, enabling them all to communicate freely, wherever they are in the world.

M2M services are part of wireless data services, together with messaging and Internet browsing. UMTS Forum Report No. 17 from August 2001, identifies seven service categories that will represent the majority of the demand for 3G services till 2010: mobile Internet access, mobile intranet/extranet access, customized infotainment, consumer MMS (multimedia messaging service), business MMS, location-based services, rich voice. (Note: simple voice services are implied).

In this report, which is the latest report dealing with 3G market, the revenue for M2M services and unified messaging is predicted within business segment of multimedia messaging services which are not directly attributable to individual business users of MMS services [5].

In the meantime, situation is changed, and there are indications that there is great revenue potentials in 3G M2M services [3]. The main reasons are:

- 3G M2M could be a component of at least first six service categories stated above
- 3G can process all wireless M2M applications, because it is down compatible with 2G and 2.5G of cellular mobile networks
- 3G is capable to guarantee the best quality of mobile service with the highest available transfer rates.

The possible wireless M2M applications are presented in the Table I. Applications are grouped according to their uses and application fields/environments. The last three columns in table indicates appropriate generations of mobile networks for handling the specific M2M applications.

As shown in Table I, some applications require high data speeds. This could be only occasional (video surveillance after alert), and there is no need for permanent (and costly) high speed connection as in fixed leased line case. In the context of wireless data, M2M solutions are ideal bridge from 2.5G business to the 3G world.

### Table I. M2M Wireless Applications [1]

<table>
<thead>
<tr>
<th>FIELD</th>
<th>APPLICATION</th>
<th>2G</th>
<th>2.5G</th>
<th>3G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fleet management</td>
<td>- Cargo tracking</td>
<td>+</td>
<td>+</td>
<td></td>
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<tr>
<td></td>
<td>- Route planning</td>
<td>+</td>
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<tr>
<td></td>
<td>- Order management</td>
<td></td>
<td>+</td>
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<tr>
<td>Home applications</td>
<td>- Control of electrical devices</td>
<td>+</td>
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<td></td>
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<tr>
<td></td>
<td>- Door locking system management</td>
<td></td>
<td>+</td>
<td></td>
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<tr>
<td>Industrial applications</td>
<td>- Traffic automation</td>
<td>+</td>
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<tr>
<td></td>
<td>- Electronic tolling</td>
<td></td>
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<tr>
<td></td>
<td>- Road usage management</td>
<td>+</td>
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<tr>
<td>Public traffic services</td>
<td>- Speed cameras</td>
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<tr>
<td></td>
<td>- Changing traffic signs</td>
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<td>+</td>
<td></td>
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<tr>
<td>Sales &amp; payments</td>
<td>- Vending machines</td>
<td>+</td>
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<tr>
<td></td>
<td>- POS terminals</td>
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<td>+</td>
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<tr>
<td>Security and surveillance</td>
<td>- Access and mobility control</td>
<td>+</td>
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<tr>
<td></td>
<td>- Surveillance cameras</td>
<td></td>
<td>+</td>
<td></td>
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<tr>
<td></td>
<td>- Property monitoring</td>
<td></td>
<td>+</td>
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<tr>
<td></td>
<td>- Environmental and weather monitoring</td>
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<tr>
<td>Service &amp; Maintenance</td>
<td>- Elevators</td>
<td>+</td>
<td></td>
<td></td>
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<tr>
<td>Telematics / in-vehicle</td>
<td>- Remote patient monitoring</td>
<td>+</td>
<td>+</td>
<td></td>
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<tr>
<td></td>
<td>- Remote diagnostics</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Telemedicine</td>
<td>- Equipment status tracking</td>
<td>+</td>
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<td></td>
<td>- Staff scheduling</td>
<td></td>
<td>+</td>
<td>+</td>
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<tr>
<td></td>
<td>- Heating system control</td>
<td></td>
<td>+</td>
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<tr>
<td>Telemetry</td>
<td>- Utility meter reading</td>
<td>+</td>
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<td></td>
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<tr>
<td></td>
<td>- Parking meters</td>
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<tr>
<td></td>
<td>- Industrial metering</td>
<td></td>
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<td>+</td>
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<tr>
<td></td>
<td>- Elevator control</td>
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<tr>
<td></td>
<td>- Vending machine control</td>
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III. Market Segments and Target Objects for 3G M2M Services

According to the M2M wireless applications presented in Table I, it is evident that market segments for the 3G M2M are both residential and business.

The usual way of looking at wireless M2M is to consider applications which fall into two broad categories: fixed M2M and mobile M2M. With fixed M2M there is a huge variety of possibilities including, for example, the control and monitoring of alarm and security systems, electronic payment terminals,
vending machines and utility meter reading. Mobile M2M cover fleet management and a vast array of automobile applications. The automobile market provides a huge opportunity for M2M with in-vehicle services such as performance monitoring, diagnostics, navigation, positioning, local information, safety and communications [4].

Additional separation, of wireless M2M could be done according to traffic. Traffic intensive M2M services are used every day or even permanently and during their use, a high volume of data / transmission speed is possible. Traffic non-intensive services are characterized by occasional use, but when they are used, a high volume of data / transmission speed is possible.

Target objects for 3G M2M services are given in the Table II. Target objects do not consist of users (because they are not human beings), but of units called end-points.

<table>
<thead>
<tr>
<th>Traffic intensive end-points</th>
<th>Mobile end-point</th>
<th>Fixed end-point (but mobile eligible)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telematics / in-vehicle &amp; Fleet management:</td>
<td>- Intra/inter urban passenger and goods transportation (road, rail, water)</td>
<td>Security and surveillance:</td>
</tr>
<tr>
<td>- Dwellings</td>
<td>- Offices</td>
<td>- Plants</td>
</tr>
<tr>
<td>- Garages</td>
<td>- Connecting business (dis)locations</td>
<td>- Telemedicine:</td>
</tr>
<tr>
<td>- Health institutions</td>
<td>- Public traffic services:</td>
<td>- Traffic information</td>
</tr>
<tr>
<td>- Speed cameras</td>
<td>- Industrial applications &amp; telemetry</td>
<td></td>
</tr>
</tbody>
</table>

Additionally, it is quite possibly that some of existing fixed leased lines with 3G transmission speeds used for M2M communications will be substituted with 3G M2M services. The consequence of that substitution will have the negative impact on number of fixed leased lines in the future, resulting in decreasing of their existing market share.

IV. GROWTH MODEL FOR PENETRATION OF M2M SERVICES VIA 3G MOBILE NETWORKS

For penetration modeling of M2M services via 3G mobile networks logistic growth model (1) is used:

\[
p(t) = \frac{M}{1 + e^{-\Delta t (t-b)}}
\]

where the growth parameter is expressed by parameter \( \Delta t \) called characteristic duration, and constant \( \alpha \); \( M \) is asymptotic maximum of penetration (depends on type of service and its target market objects) and \( b \) is time shift in years [6]. Characteristic duration specifies the time required for penetration to grow from the chosen values \( p_1 \) to \( p_2 \). For \( p_1 = 0.05 \, M \) and \( p_2 = 0.95 \, M \), the value for constant \( \alpha \) is obtained through simple algebra, \( \alpha = \ln(361) \).

Because 3G and M2M represent the newest technology and services, and there are no certain facts available - but only a plenty of speculations, both pessimistic and optimistic approach are used. That means that the number of 3G M2M end-points are estimated in interval ranged from the pessimistic value to the optimistic value.

According to in-depth analysis and analogy with penetration growth rate of similar services in the past, it is presumed that for 3G M2M services in optimistic case \( \Delta t = 6 \) years, and in pessimistic case \( \Delta t = 7 \) years [7]. Additionally, it is presumed that in the pessimistic case:

- asymptotic limit \( M \) is 20\% less than in the optimistic case
- 5\% saturation will be delayed for one year in comparison with optimistic case
- 95\% saturation will be delayed for two years in comparison with optimistic case.

Based on this concept, dynamics of 3G M2M penetration is modeled from the introduction of service \( t_i \) to its maturity \( t_m \).

As stated above, in the optimistic case the growth model is:

\[
p_{opt}(t) = \frac{M}{1 + e^{-0.98(t-t_{opt})}}
\]

and in the pessimistic case the growth model is:

\[
p_{pes}(t) = \frac{0.8M}{1 + e^{-0.84(t-t_{pes})}}
\]

Growth models are presented on Fig. 2.

![Growth model for penetration of 3G M2M services in optimistic and pessimistic case](image-url)
V. CRITERIA FOR CROATIAN 3G M2M MARKET REQUIREMENTS

This chapter will propose the criteria for the evaluation of total number of end-points. These criteria are proposed for upper-middle-income economies, according to the World Bank country classification, where Croatia belongs [7].

A. Residential Market Segment

This section analyze target objects of the residential market segment for the 3G M2M applications.

1) Dwelling Stock

By analyzing this part of residential market segment it is possible to estimate the number of 3G M2M end-points for the applications: surveillance cameras and property monitoring for target objects: dwellings.

Dwelling stock consists of residential dwellings and vacation dwellings. Vacation dwellings are usually more than 10 months empty, and mostly citizens with the highest purchasing power can afford them - so they are interested in security and surveillance of these assets.

It is presumed that ultimately 50% vacation dwellings and 20% residential dwellings will be covered with 3G M2M end-points for security and surveillance services.

2) Passenger cars

By analyzing this part of residential market segment it is possible to estimate the number of 3G M2M end-points for the applications: driver navigation, driver safety, vehicle diagnostics, location services, traffic information and route planning for target objects: passenger cars.

According to the purchasing power distribution of Croatian citizens it is presumed that ultimately 10% of new passenger cars will be equipped by 3G M2M devices. In the same time it is presumed that ultimately 1% of existing passenger cars will be, with delay of one year, equipped with 3G M2M devices. New passenger car after one year became “old” passenger car, so amount 3G M2M equipped passenger cars cumulative grows each year independently of 3G M2M devices penetration in the segment of existing passenger cars.

It is necessary to point out that similar telematics / in-vehicle and fleet management application for private owned vessels (boats and yachts) have relatively small share in Croatian market, compared with numerous passenger cars - so they can be overlaid with data for passenger cars.

B. Business Market Segment

This section analyzes target objects of the business market segment for the 3G M2M applications.

1) Business Entities with Dislocations

By analyzing this part of business market segment it is possible to estimate the number of 3G M2M end-points for the applications: surveillance cameras, property monitoring, process automation and industrial metering and for target objects: business entities sites (locations and/or dislocations).

Under the umbrella of one business entity, the strong cohesion forces exists for the (dis)location interconnection, especially for the above mentioned applications.

It is presumed that ultimately 40% of locations of dislocated business entities will have 3G M2M end-point.

2) Road Motor Vehicles

By analyzing this part of business market segment it is possible to estimate the number of 3G M2M end-points for the applications: driver navigation, driver safety, vehicle diagnostics, location services, traffic information and route planning for target objects: passenger cars, light vans, goods vehicles, urban traffic and public road transport.

The criteria for passenger cars in business market segment is the same as in residential market segment. For goods vehicles it is presumed 5 times higher percentage than for passenger cars, because cost of 3G M2M device is relatively smaller in comparison with the total cost of goods vehicle. According to this, it is presumed that ultimately 50% of new goods vehicles will be equipped by 3G M2M devices. In the same time it is presumed that ultimately 5% of existing goods vehicles will be, with delay of one year, equipped by 3G M2M devices. New goods vehicles after one year became "old" goods vehicles, so the amount of 3G M2M equipped goods vehicles cumulative grows each year, independently of 3G M2M devices penetration in the segment of existing goods vehicles.

It is necessary to point out that similar telematics / in-vehicle and fleet management application for other business owned road vehicles, vessels, locomotives, etc. have relatively small share in Croatian market, so they can be overlaid with the above mentioned data.

3) Telemedicine

By analyzing this part of business market segment it is possible to estimate the number of 3G M2M end-points for the telemedicine applications: remote patient monitoring and remote diagnostics for target objects: health institutions and health emergency units.

It is presumed that ultimately will be at least two 3G M2M end-points in each health institution (so their specialist can visit patient at patient's home or perform interventions in the field), and one 3G M2M end-point in each health emergency (mobile) unit.

4) Leased lines

Leased lines are existing platform for fixed M2M communications. It is expected that some of them with 3G transmission speeds (form 128 Kbps to 384 Kbps) will be substituted by 3G M2M end-points for the communication between business entity sites. This market segment is very similar to dislocated business entities sites, but it is oriented to business entities with only one site. Besides the ordinary data communications, possible M2M applications are: property monitoring, surveillance cameras, industrial metering and process automation.

It is presumed that ultimately 10% of existing fixed leased lines with 3G transmission speeds will be substituted by 3G M2M services. Following that, the number of 3G M2M end-
points from this part of business market segment is ultimately 2×10\% of fixed leased lines with 3G transmission speeds.

VI. TOTAL CROATIAN MARKET REQUIREMENTS FOR 3G M2M END-POINTS

Based on growth model and criteria described in previous chapters, it is possible to predict total Croatian market requirements for 3G M2M end-points from the introduction of service to its maturity. The realistic possibility is that 3G network will start in Croatia during 2004, therefore the time of service introduction is \( t_i = 2004 \). Results in relative measure (i.e. percentage of the total market capacity) are shown on Fig 3. - optimistic case, and Fig 4. - pessimistic case.

![Graph of Croatian market requirements for 3G M2M end-points](image)

Traffic intensive and traffic non-intensive end-points are analyzed separately, because revenue models for these types differ. For example: tariff policy for traffic non-intensive 3G M2M end-points could consists of relatively low monthly subscription which includes certain quantity of traffic, and additional charge for all additional traffic. In contrast to that, for traffic intensive 3G M2M end-points flat-rate tariff model (relatively high monthly subscription but without limitation in realized traffic) should be appropriate.

VII. CONCLUSIONS

The main focus of mobile operators worldwide will be to define and execute a strategy aimed at increasing their mobile data revenues. For too long this industry has been marketing technology instead of putting the emphasis on what users can do with it. M2M services are one of the options, for sure. The results of total Croatian market requirements estimations for 3G M2M end-points are promising:

- relatively high number of traffic non-intensive 3G M2M end-points (for telematics / in-vehicle & fleet management and security & surveillance M2M services) that are characterized by occasional use;
- approximately ten times less number of traffic intensive 3G M2M end-points (for telemedicine, industrial applications & telemetry and public traffic M2M services) that are characterized by everyday or even permanent use.

For the majority of mobile operators, the success will be based on whether they are able to find new opportunities for the use of 3G services. Croatian Telecom as the leading mobile operator in Croatia finds itself on this track.

REFERENCES


