MASSIVELY MULTIPLAYER ONLINE VIRTUAL SPACES – CLASSIFICATION, TECHNOLOGIES AND TRENDS

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Massively Multiplayer Online (MMO) virtual worlds are nowadays one of the most widespread and fast growing types of online interactive applications with a user base that can reach up to millions of users. The most popular type of MMOs is represented by 3D MMO games but there are also other types of MMO applications such as virtual online virtual life simulations, educational virtual spaces, virtual exhibitions, etc. In this paper, we will present the current technologies that are being used for the functioning of MMOs in optimal conditions and also we will introduce a novel taxonomy for MMOs classification based on the following criteria: type of MMOs, architectures used for simulation of virtual worlds, communication protocol and monetization.

Keywords: Massively Multiplayer Online, virtual worlds, virtual reality, client-server

1. Introduction

MMO applications enable the concurrent access of a large number of users (currently this number can range from hundreds to tens of thousands) inside the same virtual space. The users connect online to the virtual spaces, using the Internet, and the majority of the virtual words are practically accessible to anyone freely or at a reduced cost.

A user of a MMO application takes the role of a virtual character ("avatar") and then manipulates its actions. Through the avatar the user can move in the virtual space and interact with it (with the environment and other computer

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controlled entities) and with the other human users, complying with the rules and functions of that virtual space [20]. Compared to single-user or small scale multiplayer applications, in MMO applications the users can perform tasks in a collaborative and/or competitive way, together or competing with other users on a large scale. The 3D virtual space will include the avatars of all the connected users and will reproduce their actions, in real time, with extremely low latency. This latency (the amount of time between the moment when a user performs an action and the moment when he and other users see the effects in the virtual space) is a key factor for the immersion of the users and thus for the overall success of the virtual space. The ability to have low latencies, of 10-50 ms, under heavy load, is the main challenge for the design of MMO architectures [1].

To give only a few examples of existing MMOs, there are thousands of MMO games (MMOG), virtual life simulations such as Second Life, educational virtual spaces, e-learning applications, virtual exhibitions and museums [19], etc.

Regarding the financial aspect, MMO virtual spaces are creating billions of dollars in yearly revenues and this generates an increased interest from a big number of important companies that are looking to enter or further develop their presence in this thriving market.

Table 1

Top subscription based MMO titles in 2013 [16]

Nr.	MMO Title	Publisher	Total revenues (Mil $)	Market share
1	World of Warcraft	Activision/Blizzard	$1.041	36%
2	Lineage 1	NCsoft	$253	9%
3	TERA: Online	NHN Corporation	$236	8%
4	Star Wars: The Old Republic	Electronic Arts	$165	6%
5	Lord of the Rings Online	Turbine	$104	4%
6	EVE Online	CCP Games	$93	3%
7	Aion	NCsoft	$88	3%
8	Blade and Soul	NCsoft	$65	2%
9	Lineage 2	NCsoft	$45	2%
10	RIFT	Trion	$36	1%
Total			**$2.882**	

World of Warcraft [2] has a number of over 100 million total accounts with more than 7 million active users and a yearly turnover of over 1 billion dollars as can be seen in Table 1.

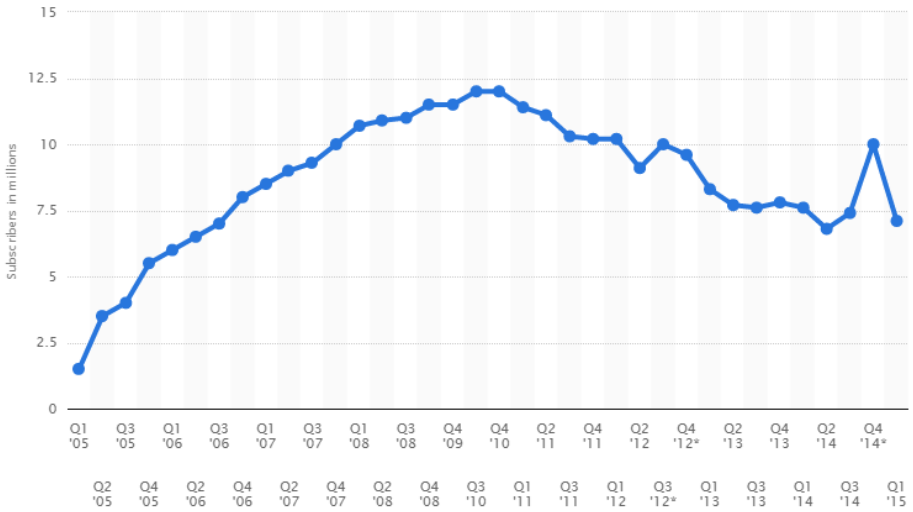

Fig. 1. World of Warcraft subscribers' evolution from 2005 to 2015 (Source: Statista 2015)

In the last couple of years, we can observe a steady change from the "buy-to-play" and „pay-to-play" subscription based model to a „free-to-play" one.

The "free-to-play" model is based heavily on micro-transactions (in-game purchases) to generate revenue. This shift can also be seen in Fig. 1 where it can be observed that the number of subscribers for World of Warcraft, that is the most popular subscription-based 3D MMO, has constantly declined starting from 2011 when it had a peak of 12 million active subscribers.

The brief spikes of increase from the graph after 2011 are due to launch of expansions but as can be seen this increase was only temporarily.

In the following sections, we will try to categorize MMOs by introducing a taxonomic scheme based on the following four major criteria (Fig. 2):

- type of simulation mechanics
- architectures used to simulate the virtual world
- communication protocol used
- monetization

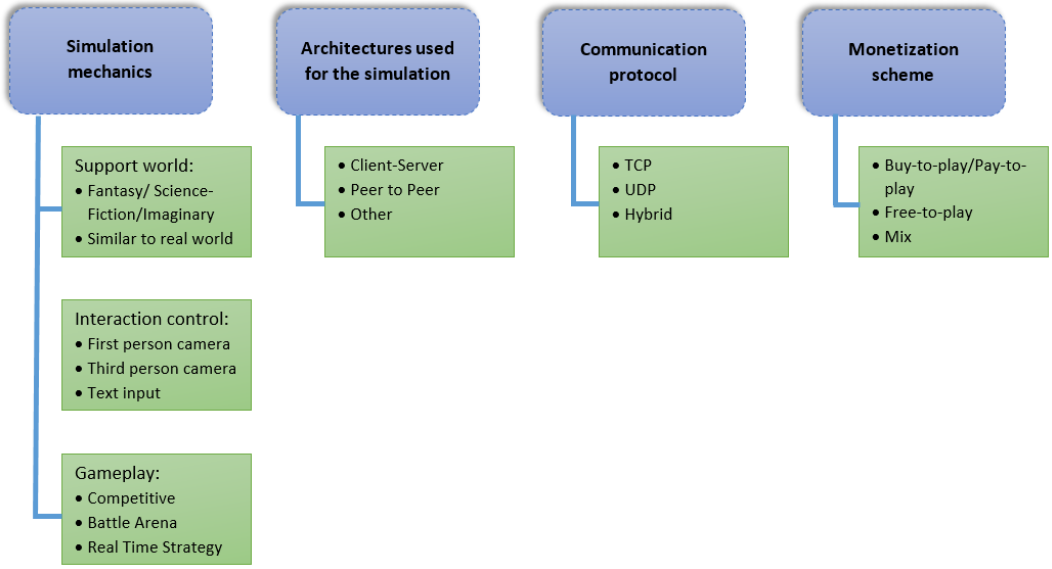

Fig. 2. Classification scheme

2. Classification based on the type of simulation mechanics

Based on their simulation mechanics (support world, interaction control, gameplay specific design), MMOs can be classified in the following way [3]:

- Type of support world used for the simulation:
  - Fantasy/Science-Fiction/Imaginary world: Massive Multiplayer On-line Role Playing Game (MMORPG): the player controls the action of an avatar that is immersed in a well-defined virtual world that is persistent and allows for a large number of players to interact; examples of MMORPGs: *World of Warcraft, Lord of The Rings Online [4], Star Wars: The Old Republic [5]*
  - Similar to a real world: Massive Multiplayer On-line Simulation of Life (MMOSLG): a type of MMO which simulates the real-world or a fictional world (but very similar to the real one) with the focus on socialization; examples of MMOSLGs: *Second life [11]*
- Type of interaction control:
  - First person camera: Massive Multiplayer On-line First Person Shooter (MMOFPS): a type of MMO where the action is focused on gun (hence the name shooter) based combat and where the player experiences the action from the perspective of a protagonist (first person); examples of MMOFPSs: *Destiny [9]*

  - Third person camera: Massive Multiplayer On-line Third Person Shooter (MMOTPS): similar with MMOFPS but where the player experiences the action by directly viewing the avatar of the protagonist; examples of MMOTPSs: *World of Tanks [10]*
  - Text input: Multi-user Dungeon (MUD): usually multiplayer games where the virtual space is described using text and where the player's interactions are executed also by means of inputting text commands
- Type of gameplay:
  - Competitive On-line Role-Playing Game (CORPG): a special type of MMORPG which is focused on competition and player versus player mechanics; examples of CORPGs: *Guild Wars [6]*
  - Multiplayer On-Line Battle Arena (MOBA): usually a type of game where a player controls a character in one of two teams that compete with each other towards a given objective; examples of MOBAs: *DOTA [7], League of Legends [8], Heroes of the Storm*
  - Massive Multiplayer On-line Real-time Strategy (MMORTS): a type of MMO where the players can build, maneuver and position structures using a set of resources available in the virtual world in order to secure given areas and to destroy the assets of the opponents; usually the player experiences the action by assuming the role of the commander that leads an army into battle; examples of MMORTSs: *Age of Empires Online*

Analyzing the data from Fig. 3, we can see that the most widespread type of MMO is the MMORPG. This trend will be maintained in the next years and is mainly due to the fact that MMORPGs have been the first types of MMOs to be created and when compared to other types of MMO applications, they are the most viable from a financial viewpoint (development costs, number of users that are attracted to such virtual spaces and generated revenue).

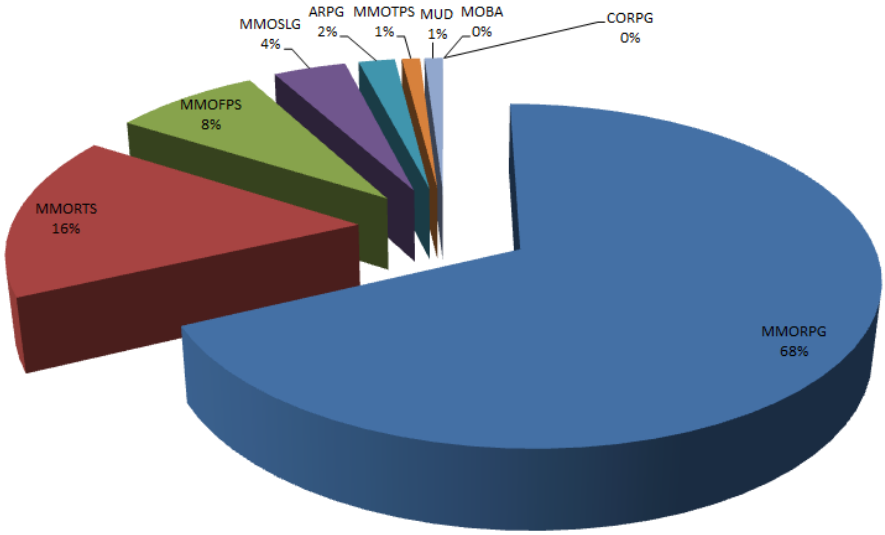

Fig. 3. Type of MMO games distribution [3]

3. Architectures and techniques used

In this section, we will briefly present the most important techniques and operations that are being employed by MMOs and classify them based on the type of architectures that are used for the virtual world simulation.

A. Techniques used for simulation of virtual worlds

1. Zoning

Usually, large scale MMOs are simulating virtual worlds that have a large geographical span. In order to distribute the computation effort and to achieve a certain degree of scalability, the virtual world is split into partitions based on a logical and/or geometrical division (pre-determined geometrical shapes such as squares or grids, separate logical divisions such as neighborhoods, regions, islands, continents, planets, etc.). In this way, a server or a group of servers can be assigned to process the computations of specific partitions in a configurable and controlled manner. This method is named “zoning” [14].

Currently there are two methods to do the zoning: either by employing a “static” zoning where the partitions are fixed from the start of the simulation and they will not change or by employing a “dynamic” zoning where the partitions can be dynamically changed (enlarged or shrunk) during the execution based on several factors that affect the computational needs for that partition. The static zoning is easier to implement while the dynamic zoning poses some design and synchronization issues that need to be addressed in the implementation.

2. Instancing

In a MMO application, an instance is a logical separated zone that can be multiplied as many times as needed; these zones are managed by a distinct group of servers that are allocated only for them. Also, depending on how many instances are created, the number of resources (servers) used can be easily dynamically adjusted to accommodate the necessary computational effort.

As specified above, an instance is a logically separated zone from the usual virtual space and its content is visible only to the specific group of users that enters that instance. Normally, the allowed number of users per instance is limited (tens of users) this leading to a better resource allocation and also allowing for a virtual environment design that can offer a better user-experience.

3. Physics simulation

In order to provide a realistic behavior for the virtual space and its users, MMO applications need to execute on the servers a large number of operations to simulate a believable physics that is as realistic as possible and also to maintain the consistency and correct functioning of the virtual world (for example an user shouldn't be allowed to pass through a solid door to access the room behind it or an user jumping should after a small amount of time to fall back on the ground and not to continue to float).

The following are a couple of the most frequent kind of operations that are related to physics simulation:

- collision detection
- collision detection response
- gravity and acceleration
- friction forces
- explosions and how they affect the surrounding environment

It is to be noted that the physics simulation operations are the most computational intensive operations that are executed on the servers of the virtual spaces. For example, each movement of a user can generate collision detection computations and this can lead to a huge number of operations that need to be processed in a very short amount of time by the servers to keep the real time functioning aspect of the virtual world.

In practice, many of such operations are not executed perfectly physically correct and approximations are being used that provide good enough results to maintain the aspect of realism.

B. Classification of MMOs based on the architectures used for the simulation

1. MMOs that implement a client-server architecture

Currently the most widespread architecture that is used by MMOs is the client-server. In this architecture, the users of the virtual space (called clients) connect to the virtual world through a login server that, after authentication, based on the user profile, redirects them to a certain realm. This realms (also named in the literature as shards) represent an individual copy of the same virtual space and this mode of operation is used in order to be able to accommodate a large number of users (ranging from tens of thousands to millions) across these individual copies and thus to achieve a certain degree of horizontal scalability. The main drawback of this method is given by the fact that the users from different shards cannot interact or if there is an interaction it is a very limited one.

The advantages of using this type of architecture are given by the fact that it is relatively easy to implement, it provides an increased degree of security and can avoid synchronization issues.

Although the client-server architecture provides all the necessary mechanisms and functions that allow an easier implementation for the simulation and management of virtual spaces, the cost at which it does it is a high one. This cost arises from the fact that a high degree of scalability needs to be assured so that a large number of users (depending on the scale of the virtual space it can reach to up of several tens of thousands) can access the virtual space concurrently. So, the current trend is that the providers and owners of these virtual spaces are trying to optimize the processing operations and to find new means to use novel computational techniques on the server-side (like for example using GPGPU computing) in order to decrease the financial cost and to obtain a higher degree of scalability.

2. MMOs that implement a peer-to-peer (P2P) architecture

P2P architectures are usually employed by MMO applications [12] that are not deployed on a very large scale (usually they don’t have a large number of users or they don’t simulate a large geographical virtual space). The P2P architecture has some inherent advantages such as using the resources of the participants for the computational needs of the simulation and also the overall robustness of the system (if a resource fails another one can be quickly assigned from the pool of existing users). This mode of operation also leads to a much lower cost of operation and maintenance for the providers and operators of the virtual spaces when compared to the client-server architecture.

The main drawbacks and challenges that the P2P architectures need to efficiently solve in order to become a viable alternative for the client-server

architecture for large scale MMOs are related mainly to the security issues that arise from giving decision and computation power in a decentralized manner to the users and also to consistency issues (due to the volatility of the resources) in order to simulate a persistent and consistent virtual world.

3. MMOs that use other architectures

There are also other types of architectures used by MMOs that extend or mix the mentioned common architectures and propose some different approaches.

First of all, there are hybrid solutions that combine P2P with client-server architectures in various ways, depending on responsibilities [12]:

- Cooperative Message Dissemination where the game state is maintained by the servers and the updates are made using P2P
- State Distribution where the game state is distributed among peers and the server handles all the communication
- Basic Server Control where the server handles only high sensitive operations like authentication, payment or critical consistency interactions and the rest is a P2P system

There are also approaches in which one type of architecture is used for the actual MMO application and another one is used for different services like micro transactions or updates. For example, World of Warcraft uses a P2P system for client software updates.

A newer architecture model that sounds promising is the Cloud Based or the Grid architecture. This approach has high potential as it takes advantage of already optimized and distributed HPC (High-Performance Computing) systems in order to meet the demanding computational resources required by MMOs.

Another new approach is to integrate or use SOA (Service-oriented architecture [13]) to distribute each service required in the MMO application.

More in-depth details about all these architectures and techniques can be found in our previous works [1][17][18][21][22][23].

4. Classification based on the communication protocol used by MMOs

This section discusses and proposes a classification for MMOs based on the most used transport protocols employed by MMOs.

An important design problem arises in each MMO's initial development: what is the type of communication protocol that will be used: TCP, UDP or a mix of them?

The network load, that can cause delay and latency, can lead to an impact regarding the game performance and responsiveness and this will significantly affect the realism of the virtual space. Also, taking into account that the user-base of MMOs is rapidly growing, the need to offer a quality and real time simulation

is very stringent and it is very important to select the proper and adequate method and communication protocol that is suited for the envisaged type of application.

Taking into account the real time and low latency requirements mentioned, regarding the choice of the communication method and protocol the general opinion is the following: "*For Real-time Strategy games, it is best to use TCP, although UDP usage can make sense in some extreme cases. For action-based games like first-person shooters or racers, UDP should absolutely be used. For role playing games, the story is not that clear—action-based RPGs use UDP, and slower RPGs and MUDs often stay with TCP*" [15].

Table 2

Transport protocol usage for popular MMOs

Protocol	MMO Title
TCP	World of Warcraft, Guild Wars, Star Wars: The Old Republic, Lineage I/II, Aion, Rift
UDP	EverQuest, Ultima Online, Lord of The Rings Online, City of Heroes, Final Fantasy XI
TCP/UDP	Dark Age of Camelot

As can be seen in Table 2, the TCP and UDP protocols are each employed by several popular MMOs and there are also MMOs that use a hybrid approach by mixing both protocols for different parts of the application. There is also an approach to use an extended UDP protocol called RUDP (Reliable UDP) that uses several algorithms to ensure better reliability with packet delivery and order. Also from Table 2 we can see that there is not a general solution that is adopted and actually the correct method and protocol of communication is highly dependent of the type and particularities of the MMO application that uses it. It is very common in modern MMOs to use different protocols for different use cases and services.

The current trend is to use UDP for highly interactive actions, TCP for standard actions and HTTP (built over the TCP/IP stack and thus a much slower protocol than only TCP), for complementary user services like messaging systems. Even HTTPS is used in some cases, like micro transactions, to ensure data privacy and high consistency.

5. Classification based on the monetization scheme used by MMOs

This section discusses and proposes a classification for MMOs taking into account the currently monetization schemes that are implemented by MMOs.

As stated before, in the last few years, there has been a consistent shift from the "**buy-to-play**" and „**pay-to-play**" subscription based model to a „**free-to-play**" model.

In the last couple of years, the MMO market has changed significantly regarding the revenue and the targeted user-base. In 2014, MMO applications

have generated more than $10 billion (Table 3) in annual revenue and this number will continue to grow strongly in the next years [16]. Therefore, it is natural that an increasing number of companies are trying to enter or further develop their presence on the MMO market.

Table 3

F2P and P2P market in 2014 [16]

Nr.	Location	Free to play revenues (Billion $)	Pay to play revenues (Billion $)
1	Asia	$3.3	$0.9
2	Europe	$2.4	$0.7
3	North America	$1.4	$0.7
4	Latin America	$0.7	$0.1
5	Rest of the world	$0.2	$0.1
Total		**$8.0**	**$2.5**

"Free-to-play" games (also called "freemium" games) can be accessed with no charge but they offer additionally (premium) content that is paid. Usually, this content is acquired using an application specific virtual currency that can be purchased (using real money) or can be acquired through gameplay (the user must invest a significant amount of time of in-game effort).

"Buy-to-play" games are acquired using real money from the start and "pay-to-play" games require a fixed paid subscription (and also it can be possible to require an initial purchase).

Although many games can be clearly classified in one of the two categories ("pay-to-play" and "free-to-play") the recent financial success of "free-to-play" games have determined providers and operators of "pay-to-play" MMOs to introduce monetization options in their applications thus leading to a hybrid model. For example, World of Warcraft that is the most popular type of "pay-to-play" MMO has introduced micro transactions and also has a "free-to-play" part (with a level cap and this leads to only a very small amount being available to free-to-play users) in order to attract new users.

One of the crucial aspects of why the "free-to-play" model has such a success is the ability to monetize and easily enter new emergent markets. Asia is currently the biggest market for free-to-play MMOs with $3.3 billion in revenues being far ahead of North America with $1.4 billion and Europe with $2.4 billion, with Tencent, being the largest Chinese MMO company, and the largest provider in the "free-to-play" online market as can be seen from Table 4.

Taking into account all the presented data, it is clear that the current trend is for companies to shift to the "free-to-play" model and this shift will continue to increase in the future.

Table 4

Free to play online market in 2013 [16]

Nr.	MMO Title	Publisher	Total revenues (Mil $)
1	Crossfire	Tencent/Riot Games	$957
2	League of Legends	Tencent/Riot Games	$624
3	Dungeon Fighter Online	Nexon	$426
4	World of Tanks	Wargaming.Net	$372
5	Maplestory	Nexon	$326
6	Lineage 1	NCsoft	$257
7	World of Warcraft	Activision/Blizzard	$213
8	Team Fortress 2	Valve	$139
9	Star Wars: The Old Republic	Electronic Arts	$139
10	Counter-Strike Online	Valve/Nexon	$121
Total			**$3574**

6. Case study

In this section we will take some of the most popular MMOs (both past and present) and we will show how they are positioned in relation to the criteria presented in the paper.

Table 5

MMOs characteristics matrix

		Simulation Mechanics							Architectures		Communication protocol			Monetization scheme		
		Support world		Interaction control		Gameplay										
		Fantasy/SF /Imaginary	Similar to Real world	1st person camera	3rd person camera	Competitive RPG	Battle Arena	Real-Time Strategy	Client-Server	P2P	TCP	UDP	Mix	Buy-to-play/ Pay-to-play	Free-to-play	Micro-transactions
Modern MMOs	World of Warcraft	x			x				x		x			x		x
	Star Wars: The Old Republic	x			x				x		x				x	x
	DOTA	x			x		x		x			x			x	x
	Second Life		x		x				x			x			x	
	World of Tanks	x			x	x			x				x		x	x
	Destiny	x		x					x			x		x		
Old MMOs	Guild Wars	x			x	x			x		x			x		
	Age of Empires Online	x			x			x	x				x		x	x
	Ultima Online	x			x				x			x		x		
	Dark Age of Camelot	x			x	x			x				x	x		
	Everquest	x		x					x			x		x		

Analyzing the data from Table 5, the following observations can be made:

- The predominant architecture used is the client-server
- Most MMOs use as support an imaginary world and implement the interaction with the environment through a 3rd person camera

- Many of the modern MMOs have shifted to the “free-to-play” model with payable “freemium" content or have introduced micro-transactions to complement the “pay-to-play” (subscription based) model

7. Conclusions

This paper introduces a novel taxonomy for the classification of MMOs using the following major criteria:

- simulation mechanics
- architectures used to simulate the virtual world
- communication transport protocol
- monetization scheme

The paper also highlights the current trends and presents some of the current important technologies, according to recent research in the domain, that are in close synergy with the proposed classification criteria.

MMOs have complex architectures and there is no such thing as a single general solution. Depending on various factors like type, consistency or latency demands, a most suitable solution can be found but only by making some trade-offs. As the technology advances, new promising solutions can be used to ensure quality and performance much easier.

Acknowledgments

Part of this work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/134398 and the TRAVEE grant of the Romanian Executive Agency for Higher Education, Research, Development and Innovation Funding - UEFISCDI, Joint Applied Research Projects programme, 1/2014(PN-II-PT-PCCA-2013-4-1580).

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