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Solutions for Optimizing the Relational JOIN Operator using the Compute Unified Device Architecture

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In this paper it is implemented the inner JOIN operator in the latest Pascal Compute Unified Device Architecture (CUDA), using two approaches developed in the CUDA Toolkit 8.0: a classical approach in which a thread selects one element from the first table and performs a binary search for the corresponding keys residing in the second table; a second approach that makes use of the dynamic parallelism feature of the Pascal architecture to solve the problem of task processing unbalance that may occur when the number of corresponding elements is different along the threads. The Compute Unified Device Architecture dynamic parallelism feature is used to invoke a supplementary kernel function in order to build in parallel the final output set of elements.

Keywords: *CUDA, Pascal architecture, Dynamic Parallelism, GPU, inner JOIN operator*

1 Introduction

In recent years, due to the unprecedented huge increase of the data volume that must be processed in a wide area of applications, scientists had to devise novel and efficient solutions for surpassing these difficulties. One of the most prominent breakthroughs in scientific computing is marked by the Compute Unified Device Architecture, released by the NVIDIA Company in 2007.

This solution allowed the developers of software applications to make use of the tremendous parallel processing power of the Graphics Processing Units (GPUs) to solve computational intensive problems efficiently and in a timely manner [1].

This major development had a massive impact on the industry, economy, and medicine and on many scientific research fields. The shift from the traditional sequential programming to the parallel processing one has opened up new paths and numerous possibilities in the information technology landscape, facilitating huge leaps and advances in technology, bringing many advantages through this new computing approach.

Until the release of the CUDA architecture, the primary role of the GPU has been solely to process graphics tasks, mainly in parallel. The introduction of this concept has provided the necessary means to the programmers for using the parallel processing power of the GPUs without having to know in detail specialized graphics programming.

The Graphics Processing Units are not targeting exclusively games developers anymore. Through the CUDA approach, the GPU becomes a general purpose programmable equipment that can be addressed by the developers in a wide area of applications.

In the last decade, there have been conducted a lot of researches that target the development of software optimization solutions using the Compute Unified Device Architecture [2], [3], [4]. Improving the software performance of data processing represents the main focus of researches from various fields, because of their multiple applications in: decision support systems [5], [6], electronic payments systems [7], [8], complex solutions for the office environment [9], temporal data mining [10].

The latest GPU Compute Unified Device Architecture, Pascal, released in the Spring of 2016, brings multiple improvements and new features to the previous versions, like: a new 16 nm Fin Field Effect Transistor (FinFET) production process that provides an improved performance and efficiency per

Watt, a new interconnect offering significant speeds up, support for a new type of memory architecture, an improved programming model and specifically optimized artificial intelligence algorithms. Thus, the Pascal architecture offers new opportunities for improving the software performance of compute intensive applications [11].
The newly developed software applications that have to process huge volumes of data differ significantly in terms of memory requirements and in the order of processing the instructions of the source code. This is the main reason why CUDA developers must take into account the hierarchical nature of parallelism, that is strictly tied to the tasks that have to be processed and the resulting processing time.
The research issues of significant importance consist in obtaining efficient and high performance parallel implementations in the Compute Unified Device Architecture of algorithms that handle complex data structures, scaling the problem to be solved according to the GPU features, thus obtaining an increased memory bandwidth and low execution time.
This article addresses the above mentioned issues in a specific situation regarding the implementation of the inner JOIN operator in the latest Pascal Compute Unified Device Architecture. The JOIN operator is a relational algebra operator that is frequently used in relational database applications. The inner JOIN operator processes two tables and returns a new one, using in the process one or more columns from each of the tables as a key and computes the Cartesian product for all the rows that correspond to the respective keys.
The article brings contributions to the current state of knowledge by developing and implementing two approaches in the latest Pascal Compute Unified Device Architecture using the CUDA Toolkit 8.0: a classical approach in which a thread selects one element from the first table and uses the method described in [1] to perform a binary search for the corresponding keys residing in the second table; a second approach that makes use of the dynamic parallelism feature to solve the problem of task processing unbalance that may occur when the number of corresponding elements is different along the threads.
Although there have been conducted extensive researches in the literature regarding the CUDA dynamic parallelism feature [12], [13], [14], to the extent of the available information, none of the works so far have analysed the impact of the Compute Unified Device Architecture dynamic parallelism feature when developing applications targeting the latest Pascal CUDA architecture.
In the following, the paper has the subsequent structure: in the 2nd section, there are presented the main features offered by the Pascal CUDA architecture; the 3rd section focuses on the main parallel programming issues that have been taken into consideration in developing the two approaches; in the 4th section are presented and compared the experimental results based on the two developed approaches; the 5th section presents the conclusions.

2 The main features offered by the Pascal CUDA architecture

When compared to the previous Maxwell and Kepler Compute Unified Device Architectures, one can observe that the most recent Pascal GP100 architecture offers substantial enhancements to the streaming multiprocessor (SM) such as: the level of occupancy afferent to the cores, and improved efficiency consisting in an enhanced performance per Watt metric.
The Pascal architecture offers important improvements, resulting in a higher overall performance than on all the other previous architectures. One can note that the Pascal GP100 architecture comprises 64 CUDA cores per each streaming multiprocessor, with a single precision of FP32 (**Fig. 1**).

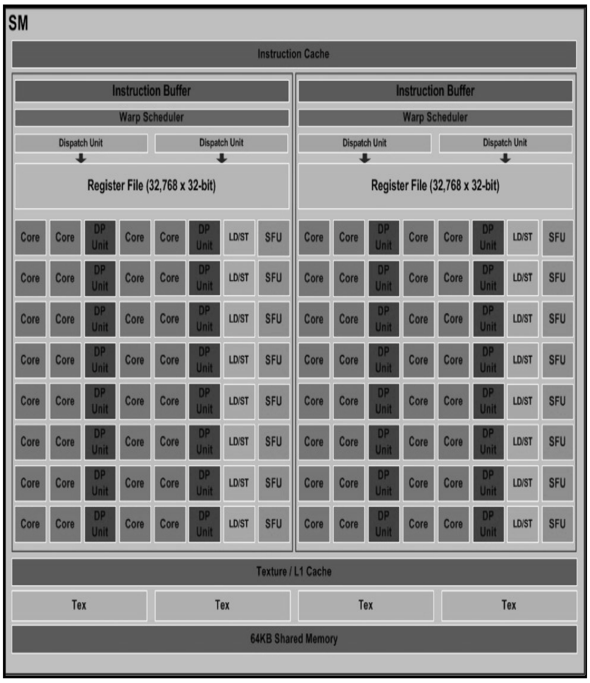

Fig. 1. A detailed insight of thelatest Pascal GP100 SM architecture[1]

In contrast with this, the previous Maxwell architecture comprises 128 CUDA cores (FP32 precision) within each streaming multiprocessor, while the Kepler CUDA architecture contains 192 CUDA cores (FP32 precision) in each of the streaming multiprocessors. In addition to this, the Pascal GP100 architecture incorporates 32 CUDA cores having a FP64 precision, thus resulting in half a rate when performing floating point computations with a FP64 precision. The Pascal architecture offers the technical possibility to incorporate in certain situations two operations having a precision of FP16 into a computing core that has a FP32 precision.

The Pascal GP100 SM architecture also contains two schedulers for warps, two buffers for instructions and two dispatching units per each processing block (**Fig. 1**). The Maxwell architecture incorporates a double number of cores than the Pascal one does, but the Pascal architecture maintains the Maxwell's register file's size and has the possibility to attain the same occupancy level of the warps and thread blocks.

The number of registers per streaming multiprocessor has remained unchanged when compared to the Maxwell and Kepler architectures but it brings a significant improvement. Although, the Pascal architecture offers a higher total amount of register memory because it has a higher number of streaming multiprocessors than the other CUDA architectures.

A comparison of the most popular Pascal architecture implementations (GP100 implemented in Tesla P100, GP102 implemented in Titan X, GP104 implemented in GeForce GTX1080) and their main technical characteristics are depicted in **Table 1**.

Table 1. A comparison between the technical features of the main Pascal architecture implementations[2]

NVIDIA GPU Architecture	GP100 - Tesla P100	GP102 - Titan X	GP104 - GeForce GTX1080
SMs	56	28	20
CUDA Cores	3584	3584	2560
Base Clock	1328 MHz	1417 MHz	1607 MHz
GPU Boost Clock	1480 MHz	1531 MHz	1733 MHz
GFLOPs	10600	10157	8873
Texture Units	224	224	160
Memory Bandwidth	732 GB/s	480 GB/s	320 GB/sec
Memory Interface	4096-bit HBM2	384-bit GDDR 5X	256-bit GDDR 5X
Memory Size	16 GB	12 GB	8 GB
L2 Cache Size	4096 KB	3072 KB	2048 KB
TDP	300 Watts	250 Watt	180 Watts
Manufacturing Process	16-nm FinFET	16-nm FinFET	16 nm FinFET

The graphic cards that implement the CUDA Pascal architecture cover a broad range of market segments, starting with game

[1] *The Figure has been created based on the figure provided by the official NVIDIA documentation sitehttps://devblogs.nvidia.com/parallelforall/inside-pascal/ , accessed on 10.14.2016, at 23:10*

[2] *The table has been created according to the official Nvidia documentation site https://devblogs.nvidia.com/parallelforall/inside-pascal/ , accessed on 10.15.2016, at 00:30*

oriented cards (GTX1080, GTX 1070, GTX 1060), up to scientific computational dedicated ones (Tesla P100). The novel CUDA Pascal architecture offers new features and innovations that provide the customers the possibility to solve problems that were previously impractical to approach, due to the huge computational requirements. Based on its undeniable advantages and prospects regarding the improvement of the parallel processing software performance, energetic efficiency and affordable price, the CUDA Pascal architecture is a viable option for developing solutions for optimizing database operations on huge datasets.

In the following section, there are analysed the main parallel programming issues that have been taken into consideration when developing the two approaches for implementing the inner JOIN operator in the latest Pascal Compute Unified Device Architecture (CUDA).

3 Analyzing important parallel programming aspects in order to develop the CUDA implementation

The most important aspects that had to be considered when developing the two approaches consisted in the appropriate management of the synchronization process, of race conditions, of atomic operations, avoiding memory leaks and dynamic parallelism.

The management of race conditions can be easily achieved when developing classical applications that run on central processing units and need only a single thread of execution. In such a situation the programmer only has to analyse the data flow in order to notice if a certain value has been retrieved from a variable before the latest updated value has been stored in it.

Nowadays, most of the existing compiling tools are able to signal and exactly point out these problems when developing single threaded applications. In the case of developing multi-threaded applications, these aspects must be meticulously analysed and prevented.

In the Compute Unified Device Architecture, the threading system automatically aims to attain the highest level of performance, often having as a result the fact that threads are executed without taking into account a certain chronology. For example, when processing an array in a certain program loop and the result from a certain step depends on the result obtained at a previous step, if the programmer allocates for every element a thread, the outcome will be correct only when the threads are executed in an ascending order and the result from the previous step has already been computed. If more threads are executed in parallel, the risks are high for the result to be incorrect or even the whole program may crash [1].

In some situations, randomly, the program may even produce the correct results if by chance a thread gets to finish the processing before another one needs the respective value. These particular issues illustrate the concept of a race condition, meaning that certain parts of a program are running in the same time to a certain execution point.

There are situations when a certain warp reaches the execution point and computes the result before another warp that needs the respective value reaches that point and there can also happen situations when the second warp reaches the execution point first, thus resulting in a computing error.

Therefore, a first characteristic for race conditions is that they manifest only in certain situations when particular conditions have been met, making it very hard for the developer to identify and pinpoint the problem.

Another important characteristic of these race conditions is that they are tightly related to the moment of executing. There are situations when introducing a breakpoint in the source code execution in order to debug the problem results in the altering of the warp's execution pattern and sometimes the error doesn't have the necessary chronology to happen.

In this situation, one has to disregard the place in the source code where the error manifests itself but has to analyse thoroughly how the threads are ordered and the pattern execution of blocks in order to pinpoint the trigger of the error.

A programmer that develops Compute Unified Device Applications must keep in mind the fact that the CUDA thread mechanism does not enforce a certain chronology in the execution of thread blocks or of the warps.

If there is even a single place in the source code where the programmer implements the logic of the program by presuming that a certain chronology will be followed by the thread blocks, then the whole application is faulty. There are certain situations when a programmer can and should state and create a certain order of the elements that are processed (for example, through sorting actions).

Nevertheless, the programmer must develop his application by taking into account that the order of execution in the equipment is indeterminate and thus, one must use a synchronization technique.

In the Compute Unified Device Architecture, the synchronization process makes it possible for the programmer to exchange data among the threads of the same block of threads or he can even exchange information among multiple blocks belonging to the same grid of blocks. Each thread has available a local memory region and its own register memory [1].

In order for the threads belonging to a certain block to be able to parallel process a dataset and exchange information with each other, they will have to store and retrieve data using the shared memory that is available at the block level.

In the Compute Unified Device Architecture, the warp has a size of 32 threads and offers to the device the possibility to schedule their execution. Therefore, in such a case the synchronization problem may arise. In the situation when the warps have the same execution paths, the operations are automatically serialized in the block, being processed in warps, at different moments of time. In spite of this, the pipelining of warps cannot be maintained consistent, due to external dependencies that may setback a warp for a period of time.

Within a block of threads, there can happen a situation when each warp inside the block retrieves data from the global memory. All the warps use the L1 cache memory except the final one that has to retrieve its data from global memory. In a situation like this, this warp will lag more iterations behind the others. It is obvious that without the implementation of carefully selected synchronization points, one cannot be certain that he obtains the correct results under all circumstances [1].

The synchronization process is mandatory in situations when the threads from different warps have to share data. When executing a CUDA program, the scheduling mechanism invokes considerable sets of block of threads that have their identifiers increase in a linear pattern. Only when a certain number of blocks have been freed from memory, the scheduling mechanism invokes new blocks of threads.

This was particularly useful when developing the two approaches for implementing the inner JOIN operator in the latest Pascal Compute Unified Device Architecture, as this made it possible to improve the access and availability of the L1 cache memory. Conversely, there is a risk of diminishing the state of the warps that are free and can be scheduled. The execution of warps and of thread blocks is spread at different points of the execution chronology and as a consequence it is absolutely necessary to assure that the computing has finished at certain points of an application.

In order to achieve this, when developing the two approaches, the "__syncthreads" primitive along with shared memory have been used to solve the race conditions and achieve correct synchronization. When developing the approaches, the synchronization was mandatory but was applied minimally as to ensure the obtaining of the correct results, avoiding the risk to keep the Graphics Processing Unit idle.

The fact that the chronology of operation is not assured also stands true for basic operations like read, write and update as one cannot be sure that these operations will finish in the same time in all the streaming multiprocessors of the Graphics Processing Unit. For that reason, when there are more threads that have to store their result in the same area of memory, the use of atomic operations assures the fact that different operations will be executed just as if they were a whole serial one.

Until recently, the problem of memory leaks was in strict conjunction with the CPU code. However, the same stands true when developing applications for the Compute Unified Device Architecture. Just like in the case of the CPU code, if a programmer allocates memory dynamically in CUDA, he must also deallocate it explicitly when the application no longer needs it.

There are some situations involving streams and events, where the Compute Unified Device Architecture runtime allocates the necessary memory the first time they are created. The programmer must use explicit instructions to deallocate the memory (cudaStreamDestroy, cudaEventDestroy), otherwise the Compute Unified Device Architecture runtime is not signalled to deallocate the memory [1].

When developing the two approaches, the "cuda-memcheck" tool has been used in order to identify and later solve problems related to memory leaks and memory usage.

The dynamic parallelism feature which is available on the Pascal architecture makes it possible for a CUDA kernel to invoke and synchronize additional child CUDA kernel functions. Until this feature was implemented in the Kepler architecture, the programmer had to invoke more kernel functions or to make sure that some threads within the block are left idle in order to be used later on. These techniques consumed high amount of resources and rendered inefficient results, especially when processing huge volumes of data.

The graphics processing unit was not used appropriately and the kernel functions couldn't store their data in the shared memory area because this type of memory exists only while the kernel does. In essence, a child kernel function can be invoked by a parent one and it is offered the possibility to synchronize the results when the child kernel has finished processing its task. The parent kernel function can make use of the result received from the child kernel function, with no implication of the Central Processing Unit.

A significant advantage that the dynamic parallelism feature brings to the developer consists in the fact that he no longer has to marshal and move the data that needs to be processed. Supplementary parallelism is obtained and can be made available dynamically to the Graphics Processing Unit's scheduling and load balancing mechanisms, in accordance to the volume of data that has to be processed. Up to the introduction of this feature, developers were compelled to remove recursion techniques when building algorithms and any other type of looping elements that did not comply to a single and flat-level of parallelism [12].

The Compute Unified Device Architecture dynamic parallelism feature makes it possible to set up and execute grids of thread blocks, in addition to delay action until the grids have completed the execution up to the threads that are already processing inside a grid of blocks. This means a certain thread that belongs to a grid of blocks and processes data can set up and execute another grid of blocks, called child grid, which will be owned by the parent grid of blocks.

A mechanism of nesting is in place, signifying that the finalization of the parent cannot be finished while waiting for the child grids to finalize. The Compute Unified Device Architecture runtime assures an implied synchronization among the parent kernel and the child kernel functions.

4 The CUDA implementation of the inner JOIN operator

The inner JOIN operator has been implemented in the latest Pascal CUDA architecture using two approaches developed in the CUDA Toolkit 8.0.

In the first classical approach, a thread selects from the first table one element and performs a binary search in parallel according to the method described in [1], in order to identify the corresponding keys that reside in the second table.

The second approach implements the dynamic parallelism feature of the Pascal architecture for solving the problem of task processing unbalance that is likely to occur when the number of corresponding elements is different along the threads.

The Compute Unified Device Architecture dynamic parallelism feature is used for invoking a supplementary kernel function that builds in parallel the final output set of elements. This approach uses the parent thread from the GPU to invoke a child kernel function. The CUDA dynamic parallelism feature has been implemented in the second approach instead of the parallel looping structures that were implemented in the classical one.

The child kernels are allocated dynamically by the parent threads in order to process in parallel the tasks. In contrast with the dynamic parallelism approach, in the classical approach, a loop structure is used by the threads within the warps to process the data in a different number of iterations, corresponding to the workload and the available resources.

One of the major advantages of the dynamic parallelism approach is that the resources of the graphics processing unit are better employed and a higher occupancy level of the GPU's resources is obtained because the parent threads invoke child kernel functions that process the tasks in parallel by means of minimal or even no control divergence.

A frequent problem when using this approach can arise due to a lack of parallelism (when the dataset has a small dimension), that makes it unfeasible to invoke the child kernel CUDA function. In this case, the processing takes place in the parent kernel function.

The patterns of memory access are different in the two developed approaches. In the classical approach, a thread accesses the memory using more loop iterations, while in the second approach, by using a single instruction, the threads of the child kernel function are contiguous and process the data in memory more efficiently, thus improving the alignment of memory and obtaining optimal coalesced memory operations along with an improved hit rate of the L1 cache.

In the case of the second approach, the Compute Unified Device Architecture dynamic parallelism feature allows to execute the same kernel function recursively, while in the case of the first approach the repeated execution of the same kernel function is achieved through multiple looped iterations.

The dynamic parallelism feature makes it possible for the parent kernel to invoke multiple child kernel functions separately that are processing the data in parallel. The execution of the child kernel functions is achieved by using a CUDA stream for every child launch in order to strengthen the chances of concurrent execution of the child kernel functions [13].

In both the approaches, the tasks are partitioned to multiple blocks of threads. In the experimental tests, different sizes were tested for both the number of blocks and threads within a block and the best results were obtained using the following allocation of resources: the number of allocated thread

blocks is the smallest integer greater than or equal to the ratio between the number of records and 1024; if the number of thread blocks is greater than 1, the size of a thread block is 1024; otherwise, the number of threads per block equals the number of records that have to be processed.
In the dynamic parallelism approach, the best results are obtained when the thread block size is a multiple of a warp size as this avoids the occurring of divergent threads within the warps. If the dimension of the thread block is not a multiple of a warp size, the parent kernel function processes the rest of the threads.
The child kernels functions cannot retrieve data directly from the shared memory owned by the parent kernel function. Whenever a child kernel function has to retrieve the data from the parent kernel's shared memory, it can receive it as a kernel function argument, or the respective value can be stored into the global memory.
Both of these methods have their drawbacks, the first one cannot pass an increased number of elements as arguments of the function, while the second method suffers an enormous penalty due to the performance characteristics of the global memory.
In the second approach, the synchronization process was used only when strictly necessary, because even if the dynamic parallelism feature offers the possibility to synchronize among child kernel functions and parent kernel functions, the synchronization process affects the overall performance of the application tremendously.
As it is stated in the official NVIDIA CUDA C Programming Guide[3], even though a single thread synchronizes, the process affects all the other threads that reside within the same thread block, even if they didn't perform a synchronization operation.
A considerable penalty that the dynamic parallelism feature brings is due to the fact that the device must keep a detailed track of the execution and also due to the whole dynamic parallelism management mechanism. In the following section, there are presented the experimental results and it is made an analysis of the two developed approaches.

5 Experimental results and performance analysis of the developed approaches

In this section, it is analyzed the performance of the two developed approaches that implement the inner JOIN operator in the latest Pascal Compute Unified Device Architecture (CUDA). The following hardware and software configurations have been used in the testing methodology: Intel i7-5960x operating at 3.0 GHz with 32GB (4x8GB) of 2144 MHz, DDR4 quad channel and the GeForce GTX 1080 NVIDIA graphics card with 8GB GDDR5X 256-bit from the Pascal architecture, the Windows 10 Educational operating system, the CUDA Toolkit 8.0 with the NVIDIA developer driver.
The average execution time for both the classical approach and the dynamical parallelism approach has been calculated using the "StopWatchInterface" included in the Compute Unified Device Architecture application programming interface, in order to define, create and manage timestamps and timers.
The set of developed tests computes the average execution times obtained in the two approaches, when implementing the inner JOIN operator, when the input data tables have a varying number of records, ranging from 64 to 1,048,576 and the output data table is the one computed through the JOIN operator. The execution time (measured in milliseconds) is computed as an average of 10,000 iterations, that has been calculated after eliminating the first ten supplementary iterations, as to be sure that the Graphics Processing Unit has attained the highest

[3] *http://docs.nvidia.com/cuda/cuda-c-programming-guide/index.html#ixzz4NGV8NesH accessed on 10.16.2016, at 19:45*

clock frequency. In **Table 2** are presented the registered experimental results.

Table 2. The registered experimental results

No.	NTIR (records)	CIT (ms)	DPT (ms)
1	64	0.015679	0.019357
2	128	0.015685	0.019364
3	256	0.016446	0.021415
4	512	0.017627	0.021592
5	1,024	0.017945	0.021749
6	2,048	0.021622	0.027614
7	4,096	0.024816	0.030771
8	8,192	0.028999	0.039590
9	16,384	0.035901	0.045851
10	32,768	0.040149	0.050384
11	65,536	0.046978	0.057401
12	131,072	0.055711	0.065138
13	262,144	0.065791	0.077154
14	524,288	0.078988	0.089885
15	1,048,576	0.095049	0.109880
Total execution time - 10,000 iterations (h)		**0.001604**	**0.001937**
The system's power (kW)		**0.261000**	
The total energy consumption (kWh)		**0.000419**	**0.000505**
A comparison between the economic efficiency of the two approaches		The total energy consumption is **17%** lower when using the first approach	

The second column of this table contains the number of total input records (NTIR), the third column contains the average execution times when developing the classical CUDA implementation of the inner JOIN operator (CIT), while the last column contains the average execution times when developing the dynamic parallelism CUDA implementation of the inner JOIN operator (DPT).

Of particular interest was to analyze the economic efficiency of the two approaches. Thus, it was computed the total number of processed records, the total CIT time and the total DPT time for all the tests, taking into account all the 10,000 iterations. Afterwards, using a Voltcraft Energy Logger 4000 meter that measures the consumption of energy, it has been measured the system's power (expressed in kW) and it has been computed the total energy consumption (measured in kWh) for each approach.

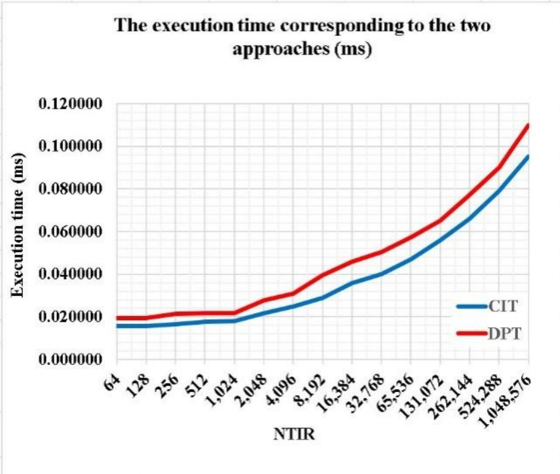

Fig.2. The execution time corresponding to the two developed approaches

After having executed the two approaches and having analysed the experimental results provided by the test suite, one can observe the following: in all the cases, the CIT value (corresponding to the classical approach) is lower than the DPT value (corresponding to the dynamic parallelism approach) **(Fig.2)**.

When running the test suite, the total execution time of all the 10,000 iterations and the corresponding system power consumption of the first approach were 17% lower than in the case of the second approach, thus the first approach offers an improved economic efficiency compared to the other one.

Although the dynamic parallelism feature allows the developer to make use of consecrated programming techniques, it suffers a considerable overhead due to the fact that the Graphics Processing Unit must monitor in detail the whole execution of the parent and child kernel functions and keep a detailed track of their execution, due to the way of how the management mechanism of the dynamic parallelism is implemented.

6 Conclusions

Both the developed approaches that implement in CUDA the JOIN operator in the Pascal architecture offer a high level of performance when processing high volumes of data (1,048,576 records processed in 0,1 milliseconds).

Although the dynamic parallelism feature allows a more robust implementation and makes it possible to generate work directly from the GPU, allowing the developer to tackle important programming techniques, like recursion, directly on the device, in the case of the inner JOIN operator the use of the dynamic parallelism in the Compute Unified Device Architecture creates a penalty on performance due to the overhead that is generated by invoking new child kernels.

The new Pascal Compute Unified Device Architecture offers an effective solution for processing huge data sets and data operators.

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Informatics Solutions Requirements for Electricity Consumption Management

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Our work is supported through a grant research project within PNCDI III competition that aims to transfer the knowledge and expertise from universities to business environment in order to improve the performance of modern technologies. The scope of our project PN-III-P2-2.1-BG-2016-0286 is to develop informatics solutions for electricity consumption analysis and optimization in smart grids. The new technology that belongs to our partner Repower Furnizare Romania SRL - electricity supplier consist in pilot smart metering system recently implemented at consumer site. In this paper we describe the smart metering system technology, informatics solution requirements, our research objectives, main software technologies and prototype architecture.
Keywords: *Internet of Things, smart metering system, business intelligent, electricity prosumers, consumption data*

1 Introduction

The proposed informatics solutions are particularly important in the current context of the European and national regulations regarding large scale implementation of smart metering systems(SMS) [1], [2], Internet of Things (IoT) concept, reduction of carbon footprint and improvement of energy efficiency [3]. In order to implement SMS, the National Regulatory Authority for Energy (NRAE) approved national targets for grid distribution operators that should be reached until 2020 (up to about 80% of final consumers should have smart meters, based on cost benefit analysis).

Comparing with previous period before SMS implementation, the final consumers and prosumers play an active role. They are more aware of consumption aspects due to new technology benefits such assmart metering applications. The volume of data provided from *SMS* and intelligent appliances (IoT) is significant and currently it is not processed. Compared to conventional electricity meters that are manually read once a month, the SMS measure aggregate/individual electricity consumption of IoT appliances at configurable time intervals (5, 10, 15, 30 min).

In this area, at international level there are researches and studies for data management described in [4], [5],[6] but at national area there are no tested or validated solution. Also, *prosumers* profiles are described in [7], [8], [9], but due to national aspects (legislation, market requirements, consumer’s necessities, demographic and infrastructure constraints), these solutions cannot be directly applied in Romania. As for the optimization models there are several approaches at national level [10], [11] and international level [12-16] and some electricity consumption forecasting models are described in [17-21]. Also, there are several *business intelligence* platforms developed for the power grid companies [22], [23]. However, these solutions require advanced customization and investments in order to be directly applied in Romania.

2 Smart metering systems

SMS measure individual electricity consumption of IoT appliances (such as cooling, ventilation, lightning systems, etc.) at configurable time intervals (5, 10, 15 minutes). These record on each phase: voltage (V), electric current (A) and phase shift between voltage and current (ϕ). Then active power (W), reactive power (VAr), apparent power (VA), power factor, active energy (Wh), reactive energy (VArh), apparent energy (Vah) and ratio between power and energy that is in/out the meter, could be calculated. SMS allow bidirectional measuring for prosumers that own solar panels, wind/biomass/diesel generators that can cover their consumption and send the surplus to the grid.

The gateways collet data that come from SMS and ensure that the data is sent to the local database. The access to the gateways is performed by web interfaces that allow the connection of any device: PC, laptop, mobile phone, tablet, etc. Data transmission is ensured by the two communication ways: PLC (Power Line Communication) and radio waves (485, 868 MHz). The main characteristics of the gateway are: open operating system (Linux), local memory (SD card) up to 32 GB, 2 LAN RJ45 with different IPs, integrated Wi-Fi, multiple communication ways (PLC, 485/868 MHz, ZigBee) and USB. Interconnection elements also known as fittings (PLC/485 bridge, 868/485 bridge, router 3G/Wi-Fi, etc.) allow the conversion of the signals and connection of the devices. Sensors are devices that record electrical and environment data (such as temperature, humidity, luminosity). Other devices include those devices whose communication protocol is known and use the data transmission management via PLC, Ethernet, radio waves, Wi-Fi, Bluetooth, etc.

3 Research objectives at glance

The main objective of the project is correlated with our partner current necessities to implement a pilot smart metering system and energy efficiency measures. Our target is to perform a business intelligence informatics prototype that will allow our partner to provide its electricity consumers with online platform for consumption management. This platform will allow our partner to monitor, process and analyze in details or aggregately the electricity consumption. The specific objectives are the following:

Developing data management model. Large volume, velocity and heterogeneity of data from *SMS* /*IoT* appliances require a model for data processing and integration. Our original contribution consists in a data mapping model that integrates structured data from *SMS* into a relational database and semi/un-structured data from *IoT* appliances into a *NoSQL* database, centralized at the electricity supplier level for performant and real-time analysis.

Developing dynamic profiles. The active role of the *prosumers* will lead to impossibility to use the existent profiles [6] and their continuously changing behavior requires adaptive and dynamic models for determining their consumption/production profiles. Our contribution consists in developing profiles and consumption/production patterns based on *data mining* (clustering, classification) and *artificial neural networks* (self-organizing maps).

Electricity consumption optimization. On one hand, flattening of the daily load curve is important for grid operators due to the fact that power plants are less required to vary their output. It also has direct repercussions on electricity grids loading, by eliminating or postponing onerous investment in electricity grids. On the other hand, final consumers such as households or retailers are interested in minimization of electricity payment. Therefore, there are two different approaches that can be treated in terms of electricity consumption optimization. Our contribution consists in developing electricity consumption models with different objective functions. We'll model the conventional and *IoT* appliances and study the effect of *prosumers'* generation sources and storage equipment on electricity consumption optimization. Based on [24], the electricity consumer can save up to 50% of the electricity payment as a consequence lower (by 30%) off-peak electricity price compared to the peak electricity price. Then, we will model and size storage equipment that would further improve the results of the consumption optimization process.

Electricity consumption forecast. We'll propose models for consumption forecasts on different time horizons. Because there is an autoregressive component of total consumption, we will develop algorithms based on autoregressive neural networks and stochastic methods [21]. Based on high accuracy consumption forecast, the electricity supplier will be able to efficiently prepare bids on the electricity markets and better plan other resources. Also, the setting of advanced tariff systems is based on both consumption profiles and forecasts.

Development of interfaces for advanced analysis of consumption data. Electricity *prosumers* need mobile interfaces and applications to monitor their behavior. Also, the electricity suppliers require intelligent platforms to analyze aggregate/detailed consumption and find out new trends in the *prosumers'* behavior based on *SMS/IoT* data. Our contribution consists in developing the *business intelligence* platform in a *cloud computing* architecture that allows: *prosumers* to configure, schedule, control and monitor their appliances and electricity suppliers to analyze, plan and forecast the aggregate/detailed consumption.

The feasibility of the project is facilitated mainly by our experience in interdisciplinary related projects [25], [26], by the cohesion of the team members and also by the collaboration with *Repower Furnizare Romania SRL* (electricity supplier) that agreed to support our initiative and provide access to their pilot data, so that we will build the models on real *SMS/IoT* data recorded at the retailer site. In this respect we have their written agreement. However, we plan to build a *SMS/IoT* environment so that we'll be able to test and validate the proposed models.

4 Informatics solutions requirements

The data volume generated by the smart metering systems can be significant and can yearly totalize millions of records for one single retailer. These data could be processed by Big Data solutions in order to improve the performance of business decisions of electricity supplier, bring new opportunities to electricity consumers, grid operators and suppliers.

The informatics solutions for the consumption management that will be developed within this project will allow:acquisition, extraction and visualization of data that comes from out of the smart metering systems; building the dynamic individual and aggregated consumption profiles; optimize electricity consumption and program the operation of electricity individual appliances that could minimize the electricity invoice and/or minimize consumption peak, efficient consumption, reduce pollution by promoting local renewable sources and allow sustainable development; identify based on individual consumption those energy intensive appliances and propose measures in order to increase the efficiency or replace them; reduce the electricity consumption and implicitly the carbon print; real time advanced analyses based on SMS data that should support strategic decisions, including consumption forecasting that is necessary for electricity market bids and performant tariff system design; perform real time, dynamic and statistical analysis of consumption data and view graphical trends and access reports.

5 Prototype architecture

Based on the above mentioned objective, we proposed a detailed architecture of the prototype with the following components (**Fig.**1):

- Data level – it includes a physical layer for the data sources gather from the SMI/IoT devices, an Extract, Transform and Load (ETL) process that extract the data from sources and load it into relational database, a central database that organize data and a data warehouse that enables multidimensional analysis for energy supplier's management team;

- Models level – it includes algorithms for prosumers' profiles determination, consumption optimization and forecasting. This algorithms will be developed, tested and validated based on the data organized into the central database;
- Interfaces level – it includes visual analytical tools for data analysis through dynamical charts, pivot tables, narratives, dashboards, selections. The dashboards will be developed with Business Intelligence tools that allow drill-down, roll-up, data rotations and sections specific to OLAP (On-Line Analytical Processing) technologies.

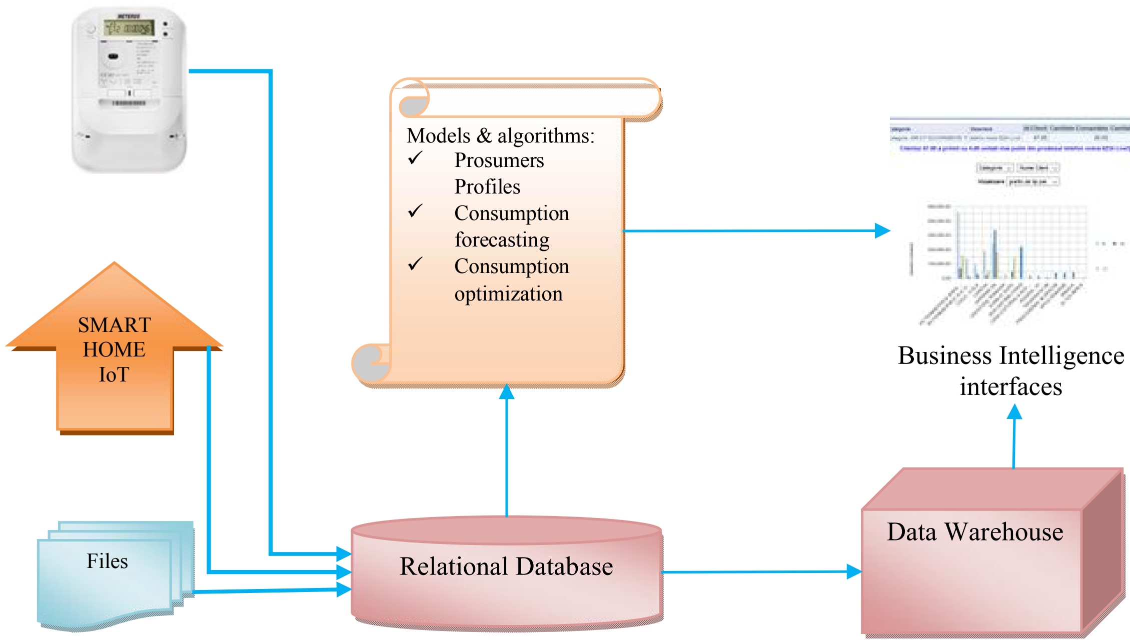

Fig. 1. The prototype's architecture

For the components' implementation we'll use MySQL database and Java platform, these technologies are described in the next paragraphs.

6 Software technologies

In order to implement the previously proposed architecture, current technologies need to be used. MySQL, Java, Business Intelligence (BI), Cloud environment are just some of the technological components that are going to be used for the software prototype that satisfies the electricity prosumers. All these technologies have a stable trend of being used and bringing new functionalities to a system that is standardized and well documented.

MySQL Database Management System (DBMS) is a multi-thread, multi-user, relational database management system. It runs like a server offering to multiple users' access to several databases. Most common programming languages (including Java) can access MySQL databases using libraries through API interfaces. Also, an ODBC (Open Database Connectivity) interface, called MyODBC, allows programming languages to communicate with MySQL databases.

MySQL works on a widely range of platforms like Windows, Linux, MAC OS, etc. The latest stable release (5.7.16) dates from 12 October 2016. MySQL capabilities include stored procedures, triggers, cursors, views, nested requests.

MySQL can be used on Cloud Computing platforms either by a virtual machine image or by a service (platform as a service).

Java platform includes the necessary software tool for developing a complete desktop or web application, like java applets that can be integrated in HTML scripts. Java programming language runs on a virtual machine (JVM), but there are also compilers for Ruby, Python, Ada, JavaScript.

Java is widely used for many years because of its maturity, multiple API interfaces and many open source libraries. Version 5.0 chanced a bit its simple philosophy by including *foreach* constructor, *autoboxing* property (passing from primitive types to the corresponding class without any necessary source code), methods with variable number of parameters, generic types, etc.

Java platform exists in four formats depending on the target application to be developed. Java Card is for small applets that run on small memory devices. Java Micro Edition (ME) is used for mobile applications, Standard Edition (SE) works for servers and desktops, while Enterprise Edition (EE) is for complex client-server enterprise applications. The current version is Java 8.

BI solutions include digital dashboards in different formats that apply data analysis and data mining techniques. These operations start from simple summarizing and sorting to clustering and pattern recognition. Also, Online Analytical Processing (OLAP) is the main tool used for processing data, through its drill-down, roll-up, slicing and dicing operations. The formats of displaying the results can be charts, tables, maps, graphs and interactive elements.

Most BI applications are Web-based because of the great opening they offer, but the best of them are Cloud-based. Cloud BI are hosted on web virtual machines as services. According to [24] Cloud BI solutions eliminate the software maintenance and the backup routines and also, by using web frameworks the costs of developing the applications are significantly reduced. The main problem that appears for Cloud applications in general, (and for BI in particular, because of its huge amount of private data exposed) is the security of data.

Cloud computing is a type of computing architecture that focuses on sharing the resources, data and applications between users. The sharing is done on–demand depending on the necessary of functionalities, storage capabilities or hardware support.

Cloud environment has three layers that need to be virtualized as services: infrastructure (the hardware components), platform (the software tools), software (functionalities brought by specific applications).

In **Fig. 2**, we propose a cloud frame for the BI application that is going to meet the energy prosumers requests. The SaaS is represented by on-demand functionalities like energy consumptions/producing predictions, consuming trends, spatial representation of energy sources, etc. The PaaS is the Java platform and the IaaS refers to sharing memory resources.

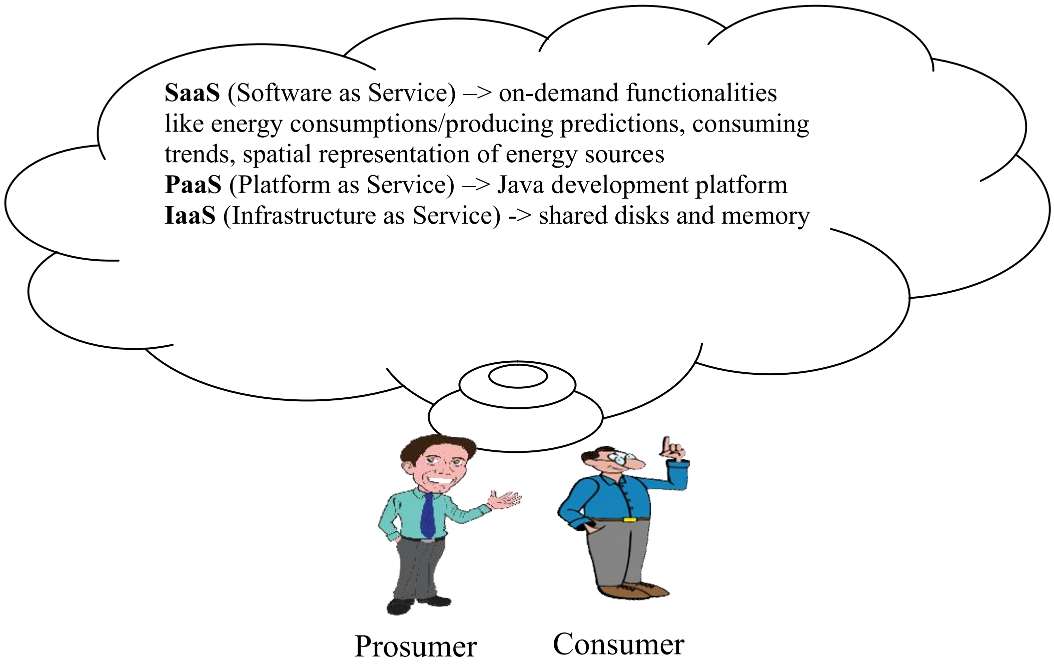

Fig. 2. Cloud BI architecture

Developing the application that is flexible, open, uses modern and stable technologies needs to take into account the Cloud architecture in which Java fits very well as a Platform service and BI offers on-demand app services. For data storing, MySQL turns out to be a reliable relational DBMS with plenty of capabilities and satisfying querying performances.

6. Conclusions and future works

In this paper we have presented related works and described the new technology – smart metering system that belongs to our partner Repower Furnizare Romania SRL. Then we have described the main research objectives related to our project PN-III-P2-2.1-BG-2016-0286 "Informatics solutions for electricity consumption analysis and optimization in smart grids"

Afterwards we have identified the main informatics solution requirements and describe the main software technology (MySQL, Java, BI, Cloud computing) that we will use in our research. Finally, we proposed a prototype architecture based on the three levels: data, models, interfaces.

In the near future, our project team will develop the data management model by integrating data from SMS and from IoT appliances into a database, centralized at the electricity supplier level for performant and real-time dynamic analysis.

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Normal Distribution Based Similarity Profiled Temporal Association Pattern Mining (N-SPAMINE)

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Temporal patterns in time stamped temporal databases are sequences of support values and hence, they are represented as vectors. This makes it challenging to obtain similar association patterns in context of time stamped temporal databases whose support trends change similar to a reference support sequence trend. The main idea of this work is to study the possibility of applying normal distribution concept to find similarly varying temporal patterns. This paper introduces a new approach, called N-SPAMINE for mining similarity profiled temporal association patterns by applying normal distribution which is first of its kind of approach for finding similar association patterns and uses the novel dissimilarity measure for obtaining dissimilarity between chosen temporal pattern and the reference. The results show that the proposed approach is correct and complete.

Keywords: *Temporal, Normal distribution, Z-score, Support Sequence, Outlier*

1 Introduction

A wide number of applications exist in our everyday life which continuously originate temporal data. A temporal dataset may be viewed as a collection of temporal data objects. A database system can be modelled to consist of data objects showing temporal behaviour for a wide range of applications. Such a database system may later be used as a temporal dataset. Consider a non-temporal database, in which the entity "employee" has attributes name, pan number, father name, voterID, adhar Number. These attribute values for a sales person do not change and remains same with respect to the changing time. This may not be true for all attributes of an "employee".

For example, consider the attributes such as address, mobile number, designation and salary. The attribute value of these attributes does not remain same and may vary over a period of time. Such attributes are called temporal attributes which show temporal behaviour. Some other examples include medical datasets, credit datasets, and co-authorship in DBLP [1]. The details of authorship, co-authorship details for an author keep varying and updating over a period of time and shows temporal behaviour. Some of the examples for temporal database include relationships with time-stamped tuple, databases with versioning. Common examples for temporal data include time series data such as EEG readings, stock market data, event sequences such as weblog data, medical data, sensor generated data and temporal databases. Temporal data mining techniques include temporal prediction, temporal clustering, temporal classification, temporal pattern discovery, search and retrieval. Of all these techniques, pattern discovery has been concentrated more by researchers from view point of temporal and spatio-temporal datasets.

Recently soft temporal pattern mining is studied which involves applying machine learning techniques to understand evolutionary behaviour of temporal data. Currently, researchers are addressing methods for discovering outliers from temporal data in soft temporal perspective which has wide scope for research in coming years. The works in this direction includes initiation from research these contributions [5, 15].

1.1 Motivation for current work

Finding temporal association patterns whose support sequence trends vary similar to a given reference trend is an important research problem in temporal databases and temporal, spatial data mining. Many real time and modern applications require finding those patterns which temporally vary in the same scale to a chosen reference trend. Discovering such temporal trends or patterns is very challenging and is not addressed in the data mining literature which is significant. The pioneer of this work is from the authors [16]. They apply the Euclidean distance measure and use the support sequence values of temporal patterns to find the similarity between chosen pattern and reference. This work of the authors motivated us and we started to work in this direction as there is further research scope in this direction. The approach for estimating temporal pattern support limits are addressed in few of our several works [17, 20, 27-31]. Approaches in [27-29, 31] adopted Euclidean distance but did not address new similarity measures for temporal databases. Also, these works did not consider the feasibility of normal distribution into consideration. In this work, we look for the possibility and feasibility of applying the normal distribution to efficiently obtain all valid temporal pattern trends that are essentially similar to the reference support trend.

Section-2 reviews literature. Section-3 discusses proposed method and measure. Section-4 demonstrates the example problem using case study, Section-5 concludes this paper.

2. Literature Review

Objects with similar temporal behaviour grouped under a common category through unsupervised approach may be called a community. In [1], given a snapshot of temporal dataset, the authors discuss the approach of discovering community outliers. Discovering such outliers is called "Evolutionary Community Outlier Detection ".

Many times it may be required to study the collocation behaviours of data objects whose information is stored as spatio-temporal data. The problem of finding the similar data objects which move together such that intra-distances between data objects do not exceed certain threshold is common in surveillance applications. Typical data mining queries includes, finding the suspiciously moving people based on the pattern movement of data objects, vehicle convoys and flocks of moving data objects. In [2], the problem of flock discovery is studied and a framework for discovering patterns in stream data is proposed.

In [3], Fabrizio Angiulli studied the problem of outlier prediction and detection. The approach proposed is an outlier detection approach which is distance based and uses unsupervised learning approach. The algorithm uses the concept called as "solving set", which is used to decide whether a new incoming stream data object is an outlier or normal.

Finding abnormal patterns is considered more important than finding normal patterns many times in the applications related to security. This is mainly because abnormal patterns are anomalies (outliers) and must be identified without missing them. In temporal data mining, detection of outliers becomes more challenging and interesting. Most of existing works treat the outliers as the binary decision problem where we either decide the data object is outlier or not an outlier at all.

In [4], Markus address, the problem by considering and viewing in different perspective such as assigning "degree of outlierness ", for each data object within a community or group. They call it as "local outlier factor", LOF. The value of LOF decides the degree that the considered data object is an outlier w.r.t other neighbouring objects. Several day to day applications generate a lot of temporal data which consists of data generated from bank transactions, traffic data, generated data from news feeds, sensor data, and medical data. To understand such evolving data, we must study the temporal behaviour of these evolving data objects.

In [5], address a new approach for discovering evolutionary behaviour of objects. Such objects are called "community trend outliers". Temporal data can be distributed data which includes temporal distributed data and spatial sensor data, time series data, stream data, network data, spatio-temporal data. A recent survey on "mining outliers in temporal data", is carried out in [6]. In their work, the authors discuss specific challenges for detecting outliers from temporal data, classification of temporal outlier analysis, various prediction models to specify few of the contributions. A framework for "community outlier detection", is also discussed and in this contribution [6].

Discovery of temporal association rules (TAR) from temporal datasets and then using these generated association rules for the figuring out rare items or outliers or unexpected trends is discussed in [7]. The outliers generally do not violate the semantics but are not frequent as compared to normal. Here, generated TARs are multidimensional, time series and quantitative in nature. The pruning of association rules is carried out by using unexpectedness measure. The outliers are detected from the stock market data considered for mining by finding stock splits. Stock splits indicate sudden change in the stock trend which constitutes outlier behaviour.

A three step approach for detecting spatio-temporal outliers from large databases is proposed in [8] which involve performing unsupervised learning and finding nearest temporal and spatial neighbours. The algorithm considers temporal, spatial and non-spatial data object values to detect outliers.

The concept of minimum spanning tree (MST) is TARs [9] from meteorological data which is one of the forms of spatio-temporal data. The importance and advantage of this approach is that we can predict the damages ahead which may be caused by climate conditions and atmosphere for people or things. The objective of using MST is to achieve optimization.

Outlier detection in most of the applications generally considers single time instance. On contrary, the outlier discovery in vehicular traffic data involves handling multiple time instances, i.e dynamic time. The work in [10] discusses considers the traffic data and propose the approach for temporal outlier discovery considering traffic data. Community outlier discovery has been one of the recent research interests concentrated.

In [11], the authors consider the temporal dataset and discover community outliers using the concept of transition matrix and community belongingness matrix.

The application of association pattern mining (APM) is discussed in context of ontology in [12] which considers semantic property not considered when using conventional text mining techniques.

Contrary to frequent items, there exist situations where the infrequent items can provide important insights into the datasets. This point forms the basis for the work in [13]. Here, the authors propose an approach for discovering both indirect and direct association patterns. Association rules are generated considering only single support values. In [14], association rules are generated by considering multiple minimum support values for discovering both direct and indirect association rules. The problem of rare item is also discussed as part of this work.

In [15], temporal and deep learning techniques are applied to mine the TARs (temporal association rules). In [16], authors consider the temporal data (time stamped temporal data), to retrieve all TAPs (temporal association patterns) that are similar to the reference and satisfy given value of threshold. A dissimilarity measure for predicting similar patterns is discussed in

[17] considering temporal dataset for temporal data. In [18], an approach for identifying routine tasks based on their temporal regularities is proposed termed as the "temporal task foot printing".
Given an "interval based event data" [19], the problem of identifying patterns from such event data is complex and challenging because of the complex relationships that exist in event based data. In this, authors propose a new approach and representation to handle such complex relationships. The approach is called the 'incision strategy", which uses the representation termed as the "coincidence representation ". An algorithm called "CTMiner" is proposed to discover frequent pattern from interval based event data which is scalable and efficient. Intrusion detection using temporal pattern is discussed in [20].
An Itemset is said to be frequent if the support of an Itemset is equal to or exceeds a specified threshold. Sometimes, infrequent Itemset may be frequent only for certain period of time. A hierarchical granular framework is considered and the TARs are generated organizing time into granules [21]. In [22], authors describe temporal sub events using five temporal relationships and extend FP-Tree algorithm for temporal domain, called TFP-growth tree. The objective is to generate association rules from video databases which are event based by using cloud infrastructure.
Each item in a temporal transaction database has its life time and transactions often contain quantitative values. In [23], the quantitative values are transformed into equivalent fuzzy values by using membership functions. A fuzzy approach is proposed to generate FTARs (fuzzy temporal association rules).
Most of the works in the literature address to find semantic relationship between entities without considering temporal nature. Implicit and Explicit temporal relationships between entities is studied and extended for web search engine in [24]. Some more recent related works includes [25-31].

3. Proposed Method

Our approach for retrieving similar association patterns from time stamped temporal database uses the concept of z-score in normal distribution and examines the possibility for applying z-score computation to mine all valid temporal association patterns applying novel temporal dissimilarity measure. Section-3 of this paper discusses the Z-score computation process for temporal support sequences. The resultant z-score computed is then transformed by computing probability value for these obtained z-scores from standard normalization tables. Section-3.2, discusses temporal dissimilarity measure which uses the z-score probabilities obtained in Section-3.1. A working example is outlined in Section-4 which explains the procedure in detail with the suitable example. The paper is concluded in Section-5.

3.1 Normalizing Support Sequences

This section explains the procedure to compute the z-score for support sequences obtained for all temporal association pattern combinations which are possible from the input temporal database. Given a temporal support sequence expressed as a vector of support values, the idea is to transform these support values into corresponding z-score values. The computation of z-score requires specifying the value for standard deviation. This value is obtained by using the novel expression designed for standard deviation as part of defining the proposed similarity measure.

3.1.1 Computing Z-score and Normalized Probability for Temporal Support Sequences

Let, TP = [TP_1, TP_2, TP_3 ……., TP_N] denote support values of temporal pattern 'TP' for 'N' time slots and the reference temporal pattern is denoted as V= [V_1, V_2, V_3 ……., V_N]. Here, the values V_1, V_2, V_3……., V_N are the support values for N time slots.

The z-score for TP w.r.t V for each time slot is computed using equation 1

$$Z_i = \frac{TP_i - V_i}{\sigma_g} \quad (1)$$

In equation (1), the variable 'i' represents i^{th}, time slot.

The temporal pattern, TP is now expressed as a sequence of z-score values represented by equation (2)

$$\mathbf{Z^{TP}} = [Z_1, Z_2, Z_3, \ldots \ldots \ldots Z_N] \quad (2)$$

These Z-score sequences obtained are then transformed into probability sequence by computing probabilities of z-score values at each time slot denoted by equation (2).

From equation (2), we get the probability vectors denoted as

$$\mathbf{P}(\mathbf{Z^{TP}}) = [\mathrm{P}(\mathrm{Z}_1), \mathrm{P}(Z_2,), \ldots . \mathrm{P}(\mathrm{Z_N})\ ] \quad (3)$$

Since, we have used the reference temporal sequence for obtaining the z-score, the resultant reference temporal pattern is now treated as a sequence of zero values (z-score values) expressed as equation (4)

$$\mathbf{P}(\mathbf{V^{TP}}) = [0, 0, 0 \ldots, 0] \quad (4)$$

The distance between probability vectors, TP and V is a sequence vector and is given by Equation (5) that is obtained by considering values of the probabilities at each time slot.

$$\mathbf{D}\ (\mathbf{P}(\mathbf{Z^{TP}}), \mathbf{P}(\mathbf{V^{TP}})) = (\mathrm{P}\ (Z_1)-0,\ \mathrm{P}\ (Z_2)-0, \ldots\ldots\ldots\ \mathrm{P}\ (Z_N)-0) \quad (5)$$

Equation (5) hence reduces to Equation (6) expressed as

$$\mathrm{D}\ (\mathrm{P}^{Z(TP)},\ \mathrm{P}^{V(TP)}) = \mathrm{P}^{Z(TP)} \quad (6)$$

Equation (6), expresses fact that the distance vector obtained is same as the probability vector of temporal pattern, $\mathbf{P^{Z(TP)}}$.

3.2 Proposed Measure

The design of proposed measure for finding similar temporal association patterns is discussed in this section. The measure uses support sequence values of temporal and reference pattern at each time slot and obtains the dissimilarity value.

We regard our contributions as follows:

1. Coming out with a novel approach i.e Z-score approach for transforming temporal support values to standard scores.
2. Design of novel dissimilarity measure
3. Defining expression for standard deviation
4. Defining threshold expression

Given a temporal pattern, TP = [TP_1, TP_2, TP_3 ……., TP_N] and the reference temporal pattern, V= [V_1, V_2, V_3 ……., V_N]. The dissimilarity between these two temporal patterns is computed using (7)

$$D_V^{TP} = \frac{(1-\mu_V^{TP})}{2} \quad (7)$$

The value of μ_V^{TP} in the equation (7) is defined in the equation (8),

$$\mu_V^{TP} = \frac{\sum_{k=1}^{k=N} e^{-(\frac{\mathrm{P(Z_K)}}{\sigma_g})^2}}{|k|} \quad (8)$$

Equation (7) is a function of normalized probability value. The probability value for every time slot is obtained by considering the z-score value at each time slot of temporal pattern and normalized distribution look up table.

The advantage of the temporal measure using the z-score probability values is that the resultant similarities are always evaluated to tight upper and lower bounds.

An upper bound value is unity and lower bound equals zero. This is not true for Euclidean measure. Also the Euclidean measure fails when we compute the distance in traditional way when using normalized probability values. This is overcome using the proposed measure.

3.2.1 Expressions for Threshold and Standard Deviation

Suppose, threshold in Euclidean space is denoted using the symbol 'δ' and standard deviation by 'σ_g'.

Equation (9) represents expression to compute the deviation which is actually a function of threshold

$$\sigma_g = \frac{\delta}{\sqrt{\ln_e\left(\frac{1}{1-\delta}\right)}} \quad (9)$$

The expression for deviation is the novel expression designed for the purpose of estimating the z-score value for a temporal pattern at each time slot. It is this deviation value which helps us in finding the z-score values.

The conventional expression that exists in the literature does not suit the current purpose. This brings the requirement for design of new standard expression. Also, the standard deviation value used remains same for each time slot, irrespective of data distribution and time slots which is another added advantage.

The threshold in normalized space is given by equation (10)

$$\delta^g = \frac{1 - exp\left[-1 * \left(\frac{\delta}{\sigma_g}\right)^2\right]}{2} \quad (10)$$

The threshold value computed using equation (10) is used as dissimilarity limit allowed for considering whether a temporal pattern is similar or not.

4. Case Study

We explain the working of proposed method to find all valid similar temporal patterns. As discussed in section-3, our approach to find similar patterns is based on Z-score and normalized probability computations for support sequence vectors of temporal patterns. The first step towards finding all valid temporal association patterns hence requires transforming temporal pattern support sequences into normalized probabilities. These values obtained are later used in the similarity measure to find if the corresponding temporal pattern in similar or an outlier.

Consider the transaction database in Fig.1. It contains 20 transactions split across two timeslots. Each timeslot has 10 transactions. Transactions TR1 to TR10 correspond to first timeslot and TR11 to TR20 correspond to second timeslot. There are at most 3 items in a transaction. i.e database is defined over A, B and C only. Such a database in Fig.1 is called time stamped temporal database.

Transactions	Items	Transactions	Items
TR1	A B C	TR11	B C
TR2	A B C	TR12	A B C
TR3	A	TR13	A B C
TR4	B C	TR14	B
TR5	C	TR15	A B C
TR6	A B C	TR16	B C
TR7	C	TR17	A B C
TR8	A C	TR18	B
TR9	B C	TR19	A
TR10	A B C	TR20	B C

Fig. 1. Transaction Database

The possible combinations of association patterns or item sets are hence seven. They are A, B, C, AB, AC, BC and ABC. The support value for these patterns is not a single value. It is a vector sequence defined over the timeslots. In this example, the number of timeslots is two. i.e the pattern is expressed as a vector of support values at two timeslots. Fig.2 shows true support values for all pattern combinations.

Pattern	T1	T2
[A]	0.6	0.5
[B]	0.6	0.9
[C]	0.9	0.7
[AB]	0.4	0.4
[AC]	0.5	0.4
[BC]	0.6	0.7
[ABC]	0.4	0.4

Fig. 2. True Supports

The traditional approach for finding, if these patterns are similar or dissimilar to a reference pattern is to apply Euclidean distance. This is because temporal patterns in our case are vectors and not single values and hence the Euclidean distance measure can be used to find distance between such vectors. However, the Euclidean distance is not directly applicable when considered normal distribution. Also, one more drawback of this measure is it does not contain strict higher bound and can even be not finite value. Fig.3 shows the distance to reference pattern for a given temporal pattern, obtained through applying the Euclidean distance metric.

Pattern	Euclidean	Pattern	Euclidean
[A]	0.1581	[AC]	0.1581
[B]	0.2550	[BC]	0.1581
[C]	0.3606	[ABC]	**0.1414**
[AB]	**0.1414**		

Fig. 3. Pattern Dissimilarity w.r.t Reference

The distance values in Fig.3 are normalized distance values and lie between 0 and 1. These distance values are obtained by dividing the obtained Euclidean distance by $\sqrt{N}$, where N is the number of time slots. This is done to make the euclidean distance have a strict upper bound limit=1. However, even such a normalized distance value computed is also not suitable and fails when we adopt the normal distribution based temporal support sequences. Our approach overcomes the above explained disadvantage and finds all valid patterns whose trend varies similar to the reference.

The computation of z-score values for pattern supports requires the value of standard deviation. Suppose, threshold specified is 0.15. This means that the dissimilarity value may not exceed 15% or it must be at least 85% similar. The deviation value for computing z-score is 0.3721. This value is obtained using the equation (9). Similarly, the threshold for normalized space is also to be computed. This value can be obtained using equation (10) after obtaining the standard deviation. For the example considered, normalized threshold is 0.08. We now show computation of z-scores for support sequences of temporal patterns in section 4.1.

4.1 Z-Score and Normalized Probability Computations

The Z-score value is obtained for support sequence of every temporal pattern. Z-score values are obtained using equation (1). The computation of Z-score and normalized probability from Z-score for all temporal patterns are shown below.

Z-Score for Temporal Pattern: [A]

$$Z_A = \left[\frac{0.6-0.4}{0.3121}, \frac{0.5-0.6}{0.3121}\right] = [0.54, -0.27]$$

$$P(Z_A) = [0.2054, 0.1064]$$

Z-Score for Temporal Pattern: [B]

$$Z_B = \left[\frac{0.6-0.4}{0.3121}, \frac{0.9-0.6}{0.3121}\right] = [0.54, 0.81]$$

$$P(Z_B) = [0.2054, 0.2910]$$

Z-Score for Temporal Pattern: [C]

$$Z_C = \left[\frac{0.9-0.4}{0.3121}, \frac{0.7-0.6}{0.3121}\right] = [1.34, 0.27]$$

$$P(Z_C) = [0.4099, 0.1064]$$

Z-Score for Temporal Pattern: [AB]

$$Z_{AB} = \left[\frac{0.4-0.4}{0.3121}, \frac{0.4-0.6}{0.3121}\right] = [0, -0.54]$$

$$P(Z_{AB}) = [0, 0.2054]$$

Z-Score for Temporal Pattern: [AC]

$$Z_{AC} = \left[\frac{0.5-0.4}{0.3121}, \frac{0.4-0.6}{0.3121}\right] = [0.27, --0.54]$$

$$P(Z_{AC}) = [0.1064, 0.2054]$$

Z-Score for Temporal Pattern: [BC]

$$Z_{BC} = \left[\frac{0.6-0.4}{0.3121}, \frac{0.7-0.6}{0.3121}\right] = [0.54, 0.27]$$

$$P(Z_{AC}) = [0.2054, 0.1064]$$

Z-Score for Temporal Pattern: [ABC]

$$Z_{ABC} = \left[\frac{0.4-0.4}{0.3121}, \frac{0.4-0.6}{0.3121}\right] = [0, -0.54]$$

$$P(Z_{ABC}) = [0, 0.2054]$$

These values obtained are then used to derive similar temporal associations not exceeding the upper dissimilarity limit.

4.2 Dissimilarity Computation

The dissimilarity between temporal pattern and reference can be computed using the equation (11). This equation is obtained by substituting (8) in (7).

$$D_V^{TP} = \frac{\left(1 - \frac{\sum_{k=1}^{k=N} e^{-\left(\frac{P(Z_K)}{\sigma g}\right)^2}}{|k|}\right)}{2} \quad (11)$$

The variable $P(Z_K)$ in the equation (11) represents the normalized probability obtained from corresponding Z-score. The dissimilarity values computed applying the proposed measure are expressed in Table.1

Table.1 Dissimilarity Computations

Pattern	Dissimilarity	Similar
[A]	0.0853	×
[B]	0.1801	×
[C]	0.1953	×
[AB]	0.0657	✓
[AC]	0.0853	×
[BC]	0.0853	×
[ABC]	0.019	✓

Comparison of Table.1 and Fig.3 shows that the proposed approach yields the same set of similar association patterns as that computed using Euclidean measure and also overcomes the dis-advantage that the Euclidean distance do not hold good for z-score approach. The only similar patterns for this example are patterns [AB] and [ABC]. All other remaining temporal patterns are outliers and are dissimilar.

4.2 Completeness and Correctness

Our approach is complete and correct as it does not lose any valid patterns that are similar. This is seen from the values computed in Fig.3 and Table.1 using Euclidean and proposed measure, applying normal distribution concept to support sequences of temporal patterns. Also, the application of normal distribution makes the statistical validation. The similarity measure has tight higher limit (=1) and lower limit (=0). This makes the proposed measure feasible for comparing the similarity degree to the threshold specified.

4.3 Monotonicity

Our measure also satisfies monotonicity w.r.t $D^{UL\ distance}$. This property makes the measure feasible for pruning the invalid temporal patterns much before than the actual point of computation in the process of discovering valid similar patterns. The discussion on monotonicity is restricted in this paper and we concentrated more on the discussion of the current approach in detail. In the future, this research may be extended to address the monotonicity property of the current measure and using this property to reduce the computation cost for improving computational efficiency. In this paper, our main objective has been towards introducing the novel approach for retrieving similar temporal patterns. We call our method as N-Spamine.

5. Conclusions

Research towards mining association patterns from time stamped temporal databases is much understudied in the literature and has a huge scope for researchers working in temporal databases, data mining, spatial databases. Also, the generated data in an IoT environment is implicitly temporal which the future is. The research in this paper suggests two new research directions for discovering valid similarity profiled temporal association patterns which include, looking into the possibility of applying normal distribution concept to mine all valid and similar temporal association patterns and the design of a new similarity measure to time stamped temporal databases. The results show that the proposed method retrieves all valid similar temporal patterns.

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An analysis of the main Characteristics and Implementation Requirements of the Advanced Metering Infrastructure Systems in Romania

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In this paper, we analyze the main characteristics and implementation requirements of the advanced metering infrastructure (AMI) systems in Romania, taking into account that the smart metering implementation enables the consumer to devise a custom-tailored strategy for his own energy consumption. First, we have studied a series of important aspects regarding the intelligent metering systems, then we highlight legal aspects regarding the implementation of AMI systems in Europe and in Romania. Afterwards, we have analyzed the types of energy consumers, their demands regarding the technological solutions for the assessment of their own consumption, registered by the smart meters and finally aspects regarding the emerging trends of the consumers' behavior. By implementing advanced metering infrastructure systems, through judicious investments and activities related to the consumers' behavior, one can obtain an improved energy efficiency at both national and international levels.

Keywords: *AMI, ANRE, Smart Metering, Data Transmission Network, Data Management*

1 Introduction

The Romanian Authority for Energy Regulation(ANRE) regulates the implementation of the advanced metering infrastructure (AMI) systems for the energy sector in Romania, through the ANRE Order no. 145/2014 [1] and the ANRE Order no. 6/2016 [2].

Through these documents, ANRE approves the proposals of the energy distribution operators for implementing the advanced metering infrastructure (AMI) systems in the case of the operators who meet the criteria for approval of pilot projects listed in the Annex 3 of [2].

The Romanian Authority for Energy Regulation (ANRE) has also approved the implementation rate of those systems by the concessionaries operators and aims the implementation of the advanced metering infrastructure (AMI) systems for approximately 80% of the customers until 2020.

In order to obtain the approval of implementing an advanced metering infrastructure (AMI) system, the energy operators should take into account that such a project must meet some minimum mandatory conditions, namely: technically – the project must be feasible; financially – the project must be reasonable and its effect must lead to considerable savings, according to the value of the investment.

According to [2], in order to disseminate information regarding the implementation and features of the AMI systems, alongside the official information provided by ANRE, the distribution operators are compelled to display on their web pages, information regarding the AMI systems implementation projects that they are undertaking.

In the following there are analyzed the main characteristics and implementation requirements of the advanced metering infrastructure (AMI) systems in Romania, studying first a series of important aspects regarding the intelligent metering systems. Afterwards, a few of the most important legal aspects regarding the implementation of AMI systems in Europe and in Romania are highlighted. Then, it is presented an analysis regarding the types of energy consumers, their demands concerning the technological solutions for the assessment of their own consumption registered by the smart meters and finally aspects regarding the emerging trends of the consumers' behavior.

2 General aspects regarding the advanced metering infrastructure (AMI) systems for energy

The advanced metering infrastructure (AMI) systems for energy consist of electronic systems, designed to measure the energy consumption while also achieving a bidirectional secured transmission of information to the end customers. These systems have the ability to provide much more information than the conventional meters, using electronic means of communication for the transmission of the information [2].

The advanced metering infrastructure (AMI) systems include a number of subsystems, namely: subsystems for measuring (include meter, which secures access to the equipment, transformers); subsystems for the transmission of information (communications network); subsystems for data reception and managing (**Fig. 1)**.

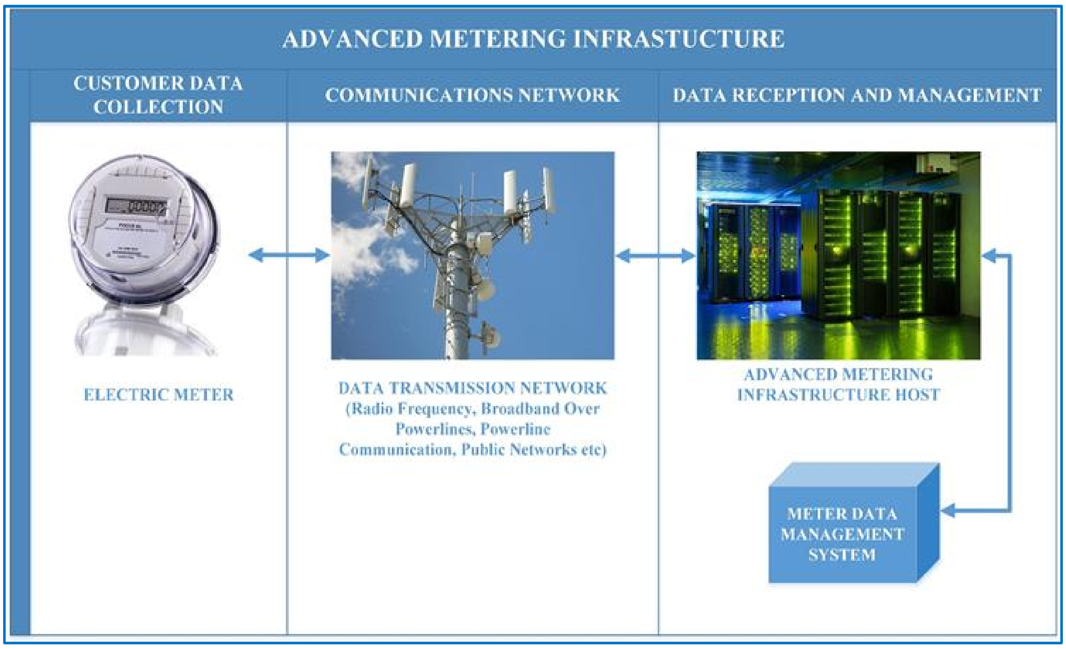

Fig. 1 Advanced metering infrastructure (AMI) systems

(The figure has been developed using the software Visio 2016 by inserting elements of "Online Pictures" type, marked with a reusable license of the "Creative Commons Licenses" type)

The advanced metering infrastructure (AMI) systems for energy must offer a series of mandatory and optional features defined in the Annex 1 of [2]. By implementing the AMI systems, a more efficient administration of tariff plans is achieved, by monitoring consumption in real time and by using the instant data transmission.

The installation project of the AMI systems, in terms of energy consumption, thermal energy and natural gas, was launched in the European Union that provides grants to implement AMI [3]. In Romania, ANRE launched in 2013 the project for advanced metering infrastructure. According to the [3] report, the plan for implementing the AMI system within the energy market in Romania targets a period of 20 years (2013 -2032), within which until 2020 approximately 80% of customers will be covered and until 2022 the AMI installation will be performed for all the consumers.

The implementation of these systems is an important step in the liberalization of the energy market (and the gas), planned for 2022, thus offering to the consumers the opportunity to choose and change their energy supplier at any moment. In addition, the AMI systems contribute to the energy efficiency at national and European level.

After considerable investments, a smart grid will be achieved, as a result of implementing these systems. The smart grid represents a symbiosis between the components of a conventional power network and elements related to the communications and information technology, complementing the functionality of the electric grid. According to the ANRE reports, the implementation of the AMI systems aims primarily the energy market as this is the largest of the three targeted markets (energy, gas, heat).

This market addresses a number of 9.000.000 consumers, as follows: 8.38 million households, 600.000 micro, small and medium enterprises, 20.000 large consumers (local governments, public authorities, companies). The report [3] estimates that for the energy market, the investments in AMI will bring the fastest and substantial benefits, including the investments' amortization. For the natural gas market, the report expects that the benefits will be reduced, while in the case of the thermal energy the benefits brought by the transition to the AMI systems are insufficient compared to the investments needed for implementing those systems. In this case, the efficiency should be achieved at the thermal power stations level and at the transport infrastructure one, in order to reduce losses.

Taking into account the implementation pace of the AMI systems by the concessionaries operators, proposed by ANRE, the report [3] estimated that the investment has a return of 43.8% and a net positive present value of 1.17 billion lei. In the case of the gas market, the net present value is negative (−72,000,000 lei), but the investments in AMI implementation may be delayed by operators, because for this market The European Commission did not impose certain targets. In order to reduce the spending, the same company might deliver both the energy and natural gas to the end customers.

Currently, the cost of a smart meter device is about 140 Euro, therefore the necessary investment for acquiring the energy meters for the 9,000,000 customers amounts to about 1,260,000,000 Euro. On the other hand, in order to implement the AMI system, one requires infrastructure investments in the construction and installation of equipment that processes the data received from the consumers. In order to recover the investment, in the first step the customers' bills will increase, but one expects that these will decrease over time, as the consumption reduces, due to the intelligent metering systems. In this way, the recovery of the initial investment is ensured [3].

The core component of the AMI, the meter, must ensure on the one hand the submission of periodic consumption registrations and the evolution indexes to the end customer and third parties, and on the other hand should provide storage space for the data during specified periods of time. Based on these systems, one will record and transmit data regarding the consumption on a daily basis. The meter must transmit data remotely to the distribution operator, must offer the possibility to update remotely the software and the different types of billing tariffs, according to the existing regulations. One of the major advantages that the implementation of such a system brings to the end user consists in the fact that he can change his billing plan according to his own needs [3].

An important issue that the energy distributors will have to manage along with the implementation of AMI systems is the fact that they should ensure that the data transfer is performed wirelessly (through Wi-Fi or mobile data), or by using the energy grid (which would result in smaller costs than using the wireless transmission) [3].

Installation of AMI systems brings to the consumers a series of benefits including: real-time identification of faults that facilitates the rapid intervention when having to solve them; the fast detection of areas where the energy parameters do not correspond to the quality standards, or there have occurred interruptions in the power supply; the ability to read data remotely, in real time; the billing accuracy. Basically, the smart meters provide accuracy, precision and efficiency in the reading process, in the recording of the consumption data and its secure transmission, in eliminating payment based on consumption estimation, in ensuring the continuous monitoring and effective intervention when incidents occur, while providing transparency on real time consumption to the customers [4].

In the following we analyze a series of legislative issues regarding the implementation of AMI in Europe and in Romania.

3 Legislative issues regarding the implementation of AMI in Europe and in Romania

At the worldwide level, there are more countries that have set up and adopted regulatory frameworks and have imposed deadlines regarding the putting into operation of the smart metering systems and, in some cases, of the smart grids [3].

In Europe, Italia has become the first country that has implemented automatic smart reading meters for more than 30,000,000 of its citizens. The national regulatory authorities have set clear objectives for the implementation of smart metering systems (especially for gas consumption, as electricity consumers are already benefiting from these systems), and imposed annual penalties on suppliers who fail to achieve the defined targets [3].

The Nordic countries have implemented these technologies as well. Sweden, for example, has mandated the installation of more than 5,000,000 smart meters by the end of the year 2009. In Denmark, although there are no legal provisions regarding the installation of smart meters, there have been conducted a series of large-scale implementations. Profile companies in Denmark offer to their customers an advanced market model and a structure that includes multi-utilities. Finland covered 80% of its households with electricity smart meters at the end of 2014 and the installation process carries on.

Norway aims to complete the installation of smart metering systems by the end of 2017. The Norwegian authorities have developed a methodology that compels the utility companies to implement smart metering systems that meet certain requirements (for example, the reading must be performed at 15 minutes intervals, options to connect and disconnect remotely, encrypted communication and integrated equipment for water and gas consumption).

Spain, France and the United Kingdom are the most active markets for electricity and natural gas. Spain has mandated the installation of a smart metering system that became operational by the end of year 2014 and its implementation must be completed by the end of the year 2018.

In France, the national energy regulator has imposed a mandatory implementation of smart metering for all the electricity consumers by the end of the year 2016 (with a coverage of at least 95%) and the manager of the gas distribution network is preparing to introduce gas smart meters to all the customers.

In the United Kingdom, the British government announced its plan to install 53 million electric and gas smart meters in households and companies by the end of the year 2019.

However, national authorities in some countries have not imposed strict targets for the implementation of smart metering systems. In Germany, for instance, electric and gas smart metering systems must be installed in new buildings, while the owners of existing buildings can optionally choose to implement this technology.

In most of the countries, the decisions to implement smart metering systems are based on a cost-benefit analysis for the investors and for the society as a whole. In most of the cases, the benefits are significant for the society, but the investments are not always profitable for the investors [3].

In the United Kingdom, a study conducted by the Energy Saving Trust revealed that within each household one could achieve savings of 10% per year on energy bills by implementing smart meters. These results were tested using pilot projects, run by Scottish and Southern Energy, funded by the Department of Energy and Climate Change and the national regulatory authority.

As a result, the government has concluded that the implementation of smart metering systems is the most effective way to help customers reduce energy consumption in the context of this country's objective to reduce CO_2 emissions by the year 2020. In addition to this, the installation of smart meters showed a reduction of 2.8% in energy consumption [3].

In Ireland, the Energy Regulatory Commission (CER) published the results of a pilot project for implementing smart meters, developed with the support of more than 10,000 customers. These results reflect a decrease of 2.5% in electricity consumption for households, with a peak demand reduction of 8.8%.

Out of the total customers, a percentage of 82% has made changes in their energy consumption behavior and it was observed that the information displayed on the smart meters that were installed in these homes had a significant role in reducing the energy consumption.

The results showed that the implementation of smart meters brings also benefits to consumers with limited incomes or for those households that typically receive state subsidies, enabling them to reduce their electricity bills and modify their consumption behavior [3].

In Italy, after having obtained a great success by implementing smart meters for electricity, the regulator authority has conducted a cost-benefit analysis before announcing in 2008 the mandatory installation of 21,000,000 smart gas meters out of which 19,000,000 must be installed before 2016.

On the other hand, in Sweden, the installation of smart meters was not explicitly mandatory but there was an implicit requirement, as from July 2009 the legislation stipulates reading hourly all the electricity meters, which led to the widespread implementation of smart meters.

The decision to read the meters hourly was taken following a positive cost-benefit analysis conducted in 2010 that showed significant gains in terms of energy efficiency for households whose consumption exceeds 8,000 kWh [3].

The Dutch government announced the mandatory installation of electricity smart metering systems for all the 7,000,000 households in the country until the year 2013, based on a cost-benefit analysis that showed positive results. However, the implementation of smart metering was interrupted and postponed in 2009 because of concerns related to privacy among consumers.

In this context, the government sought solutions in order to obtain the benefits of an improved energy efficiency (proven through analysis and studies) while ensuring and protecting the consumers' privacy. This was achieved by setting different deadlines for the implementation of smart metering for electricity and gas, and by making optionally the transition for customers.

In Germany, the smart metering policy is also mainly driven by the customers' demand and the state hesitated to impose strict targets due to the public's strong reluctance on personal data protection. From the investors point of view, one of the major advantages of installing such systems is the reduce of technical and commercial losses in electricity supply.

This was one of the key reasons for implementing these systems in Italy and Poland, where studies have indicated a potential reduction of commercial losses by 60% (in some cases even up to 90%).

In Romania, the AMI implementation is regulated by the ANRE Order no. 145/2014, regarding the deployment of smart metering in the energy field [1], which was subsequently amended and supplemented by the ANRE Order no. 6/2016 [2].

These documents define the intelligent

metering systems, specify their mandatory and optional features, stipulate the conditions that must be fulfilled by the projects regarding the deployment of smart metering and the implementation pace of these systems.

The Order [1] also stipulated clear guidelines for the concessionaries operators regarding the implementation in 2015 of pilot projects and evaluation of specific aspects within the distribution networks, in order to establish the final implementation terms of intelligent metering systems.

For the year 2016, the Order [2] stipulates the obligation of the concessionaries operators to monitor the implementation of pilot projects regarding the smart metering systems, developed in the year 2015 and assess their costs and benefits. The National Regulatory Authority for Energy monitors the results registered within the projects regarding the implementation of intelligent metering systems.

After evaluating the results of the projects regarding the implementation of intelligent metering systems, the concessionaries operators propose to the ANRE plans for implementing the intelligent metering systems for the period 2017-2020 (up to January 10, 2017).

Using the results of pilot projects carried out by the concessionaries operators, ANRE performs (using an independent specialized consultant) a cost-benefit analysis on the implementation of the intelligent metering systems and then, based on this study, develops the national plan for the period 2017-2020 regarding the implementation of intelligent metering systems. In this purpose, it is essential that the concessionaries operators submit to ANRE all the required data and information, useful for achieving the cost-benefit analysis. Based on this analysis, ANRE approves until 31 March 2017:

- a national schedule calendar regarding the implementation of intelligent metering systems that contains the dates of the various implementation stages
- a national schedule calendar regarding the implementation of intelligent metering systems, containing details about each distribution operator investments, the amount and funding sources
- measures and means of information for the end customers.

The Order [1], amended and supplemented by the subsequent order [2], requires the concessionaries operators to display on their web pages information regarding the implemented intelligent metering systems (their number, technical data, the mandatory and optional features, the communication type with the subsystems that manage the information).

Both operators and concessionaries distribution suppliers are obliged to disclose in the electricity bills if there are implemented intelligent metering systems at the consumption place, in order to inform the end customer.

The Order [2] stipulates that at the request of the end customers connected to the energy grid, the transmission system operator can offer to the customers intelligent metering systems, complying to the specifications of the Order. The Order also stipulates that the implementing regulations of the intelligent metering systems may also apply to other distribution operators, outside the concessionaires, on their request.

The Order [2] contains five annexes.

Annex 1 provides a range of mandatory and optional features for the intelligent metering systems. The mandatory features of the intelligent metering systems take into account:

- the end customer (the intelligent metering system must: transmit to the end customer and to a third party designated by him, the system readings; update frequently the system readings, in order to facilitate energy savings)
- the concessionaire distribution operator (the intelligent metering system must: allow the concessionaire operator the remote reading of meters; facilitate the communication between the measurement subsystem located at the consumption place and the subsystem for the

transmission of information; readings must be performed frequent enough as to be useful for the network's management)
- the commercial aspects related to the energy supply (the intelligent metering systems must: support the use of advanced billing systems; facilitate the remote control of connecting, disconnecting and power limitations)
- the aspects regarding data protection and security (the intelligent metering systems must: ensure the secure transmission of data, prevent and report the unauthorized access)
- the decentralized production (the intelligent metering systems must: ensure the possibility of measuring the absorbed, delivered and reactive energy)
- the intelligent metering systems must facilitate the fast automatic identification of damages, reducing the necessary time to repair them; facilitate the monitoring of the energy's technical parameters
- the intelligent metering systems must allow, through their infrastructure, the integration into the transformer stations of balance meters (facilitating the losses identification).

The optional features of the intelligent metering systems aim:
- to achieve the communication with the receptors situated at the end customer's location and with other utilities' meters
- the information received from the meters must be stored by the data management subsystem for at least the billing, the payment or the claiming period
- the infrastructure of such systems should enable the installation of additional meters (without replacing the existing elements)
- the storage capacity of the measuring and information transmission subsystems must be large enough so that the data can be stored for a certain period of time.

Annex 2 refers to the description of pilot projects regarding the implementation of the intelligent metering systems. This Annex stipulates that the concessionaries distribution operators must send a series of information to ANRE, regarding the estimated data for the pilot projects that have to be endorsed and also data obtained after the pilot projects fulfillment.

These data contain information regarding the concessionaire distribution operator's name, the number of proposed and fulfilled pilot projects, the development areas of these projects, the technical parameters of the energy networks within each pilot project, the detailed features of the pilot project, showing that it meets the requirements.

Annex 3 specifies the criteria for approval of the pilot projects regarding the implementation of the intelligent metering systems in the energy field: the correlation of the corresponding investments of these projects with the provisions of the investment programs; the share of the total value of investments in the implementation of the intelligent metering systems, from the total investment annual plan; the comparative study of unit costs, providing necessary data for achieving the cost-benefit analysis; the mandatory use of balance meters; the analysis of costs arising from the investments in the distribution network in order to implement the intelligent metering systems.

Annex 4 presents general data of the implementation plan of the intelligent metering systems in the energy field that have to be completed by the concessionaires operators: data regarding the network in which the intelligent metering system will be implemented; the technical solution adopted for the implementation; data regarding the security of the intelligent metering system; the confidentiality; financial data; the additional estimated costs; the timing of the investment plan regarding the implementation of the intelligent metering systems, for each year during the 2017-2020 period; the percentage and the value (in thousands of lei).

Annex 5 defines a number of 29 indicators used to assess the intelligent metering systems' implementation. These indicators are divided into several categories, depending on the covered field: the implementation status of the intelligent metering system; the intelligent metering system's structure; the economic effects of the intelligent metering system's implementation; the performance (in terms of quality) and the security.

The three percentage indicators that assess the implementation of the intelligent metering systems are:

- the implementation degree of the smart metering systems in the lease area, for the residential customers, computed as the ratio of the number of residential customers for which the smart metering systems have been installed and the total number of residential customers from that area;
- the implementation degree of the smart metering systems in the lease area, for the non-residential customers, computed as the ratio of the number of non-residential customers for which the smart metering systems have been installed and the total number of non-residential customers from that area;
- the implementation degree of the balance metering systems, computed as the ratio of the number of installed balance metering systems and the total number of balance metering systems planned to be installed, according to the intelligent metering system's implementation project.

In the following we present and analyze the types of electricity customers.

4 Types of electricity customers

The main participants at the retail electricity market are the providers, the end customers and network operators. The end customers buy electricity for their own consumption and eventually for the consumption of the end customers who are connected to their places of consumption. The end consumer of electricity is an individual or a legal person who consumes electricity under a contract whose electrical installations are connected to the source system of the supplier. Electricity consumers can be classified taking into account several criteria [5].

Thus, depending on the intended use of the consumed electricity, end customers fall into two categories [5]:

a) residential end customers;
b) non-residential end customers, meaning those customers who are buying electricity for their own use, different from household use (this category includes producers, suppliers, network operators that buy energy for their own use).

In what concerns the non-residential end customers, in terms of the power approved by the connection technical certificate, the consumption points can be of two types [5]:

a) with low consumption, if the approved power is less than or equal to 100 kW (in which case the customer will be called a small non-residential customer);
b) with a high consumption, if the approved power is greater than 100 kW (in which case the customer will be called a high non-residential customer).

In terms of the duration of electricity consumption, stipulated by the contract, the customers can be classified as [5]:

a) temporary customers;
b) permanent customers.

Depending on the number of consumption points, the electricity customers can be of two types, namely [5]:

a) customers having a single point of consumption;
b) customers having multiple points of consumption.

In the following, we examine the customers' requirements related to the available technical solutions that analyze their own consumption recorded by the smart metering systems.

5 The customers' requirements regarding the IT solutions for the analysis of their own consumption recorded by the smart metering systems

The requirements of the customers concerning the IT analysis solutions of their own electricity consumption recorded by the smart metering systems can be summarized as follows:

- the measurement and evaluation mechanisms must ensure the transparency of information regarding the electricity consumption and the production, transport and distribution costs, highlighted in the invoice issued by the supplier;
- the metered data must be stored for a reasonable period of time in order to support possible complaints;
- the smart metering system must allow the consumption assessment using multiple billing plans, achieving simulations that can substantiate an adequate consumption pattern, efficiently adapted to the goals and the means of accomplishing it;
- the smart metering system must allow the obtaining of consumption forecasts that have acceptable margins of errors (both technologically and economically) and the possibility to correlate the consumption's evolution with the production plans, the transporting capacities and / or with the distribution;
- the power quality must be monitored permanently, the technical and non-technical losses must be reduced;
- the system should safeguard the collected data and their processing results with a maximum security level, because by using these data one may deduce information that could shape specific consumer profiles or lifestyles.

In the following, we present and analyze a series of modernization trends in the electricity consumer's behavior.

6 Aspects regarding the emerging trends of the energy consumers' behavior

The energy efficiency improvement can be achieved through a harmonious combination of infrastructure investments and activities related to the consumers' behavior. By implementing a balanced system of investment and behavioral measures it is facilitated the energy saving, the sustainable development of business, of economy and of society as a whole.

An essential factor that determines the modification and modernization of the energy consumer's behavior lies in the human interaction with new technologies, with modern smart devices, with means of generating energy from own sources, with smart metering devices in the energy field, which generates an active role of the consumer regarding the power management.

When analyzing the impact of human interaction with new technologies, on the emerging trends of the consumers' behavior, the relevant dimensions are [6]:

- from the cultural point of view, the implementation and expansion of the new devices provide quick access to information. These devices have a strong social component among youth people (mobile phones, televisions, computers that contribute to the development of interpersonal communication), in opposition to a certain reluctance and even fear of technology among the elderly;
- regarding the comfort, the implementation of the new technologies brings modifications to the consumers' behavior and habits, to their daily activities; for example, the implementation of the intelligent metering systems offers to the consumer the indisputable advantage of controlling the energy consumption in real time;
- regarding the cognitive impact, the emerging technology brings advances to the human society as the consumers are adapting, keeping up with technology. An essential element that must be taken into account is the feedback stage that must take place in a short time interval after the consumption. For example, in the case of the smart metering devices, they provide real-time information regarding the consumption.

At the European level, many of the measures that have as a purpose the attaining of energy efficiency are based on implementing new technologies and on the consumer's accommodation to them. In reality, in many cases this interaction is an ongoing challenge, imposing the adapting of

decisions to the specific conditions of each consumer.
The issue of producing and using the energy in a more efficient manner represents a major concern at both international or national levels and also among consumers, whether they are industrial or residential ones.
The authority's involvement in achieving energy efficiency is noticeable by legislation and actions at all levels (local, regional, national or even European), while the consumer's awareness is achieved gradually, the changing of their behavior being less influenced by regulations, but rather by technological, economic and potential savings aspects.
In recent years, the fast technological development offers more and more efficient technical solutions, thereby influencing the end energy customers' behavior. Nowadays, the consumer has a wide range of options, from technical solutions that enable him to assume an active role in managing his consumption, to the use of alternative renewable energy sources.

7 Conclusions

Smart metering allows the customer to establish a power consumption strategy custom tailored to his own needs and to the dynamics of the consumption schedule, correlated with an adequate billing plan. On one hand, the smart metering systems assure through their implemented features that the customers have access to accurate real-time information and on the other hand, they provide useful information for improving the electricity distribution process and overall quality. In addition to this, by helping to improve the feedback mechanisms, the smart metering systems facilitate the development of new services for the end customers. The integration and deployment of smart metering in a power management system helps improve the communication and control possibilities between the customers and the suppliers, optimizing the electricity consumption along with its production and distribution process. Therefore, the existence of an adequate infrastructure for the development and implementation of an intelligent electrical network that facilitates the exchange of valuable information between the producer, supplier and customer becomes mandatory.

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