Implementation of series-parallel system for calculation of individual heat consumption and optimization of heat distribution in vertical heating systems in buildings

Author: Sergiu Ungureanu Engineer – energy auditor

Abstract. *In this paper, we will present and analyze the methodology for calculating the consumption of thermal energy for apartments located in multi-story buildings with a vertical distribution system for thermal energy. The methodology allows to individually regulate the consumption of thermal energy and calculate the consumption of thermal energy for each room and each apartment (office) in buildings with a centralized heating system with vertical distribution. The proposed solution is simple and does not involve large inconveniences or implementation costs for the system and each user.*

Key words: thermal vertical, digital temperature sensor (thermocouple), bypass pipe, water meter, telemetry, consumer cell, data transmission and reading system, CHSS.

Abbreviations used: vertical system of heat distribution in buildings - vertical system; Vertical riser for heat distribution - vertical riser; Centralized heat supply system - CHSS

Introduction. In the Republic of Moldova and in many other countries of the former Soviet Union and not only, apartment houses and multifunctional buildings (offices, production halls, warehouses, etc.) that were connected to a centralized heating system, and the distribution of heat was provided through radiators, connected by pipelines in a vertical system. So that, for the building, the heating fluid (hot water) flows through the pipeline, then in branches to vertical pipes (from the top to the bottom or from the bottom to the top), which supplied heat to each radiator located on different floors of the building. The heat carrier (water) circulates successively along the entire vertical along all floors of the heated building.

This also means a number of inconveniences, that, during the economic crisis and the decline in the population's solvency, played a critical role in the disappearance of many centralized heating systems in many towns, in particular due to the accumulation of numerous debts to the supplier and the technical degradation of centralized heating systems. The main inconveniences are: the inability to regulate the heat flow individually, ignorance of the exact heat consumption of a particular consumer (which led to issues of questioning correctness of payments), poor heat quality due to excessive cooling of the heating fluid for the first vertical consumers, and cold fluid (water) for the last riser consumers.

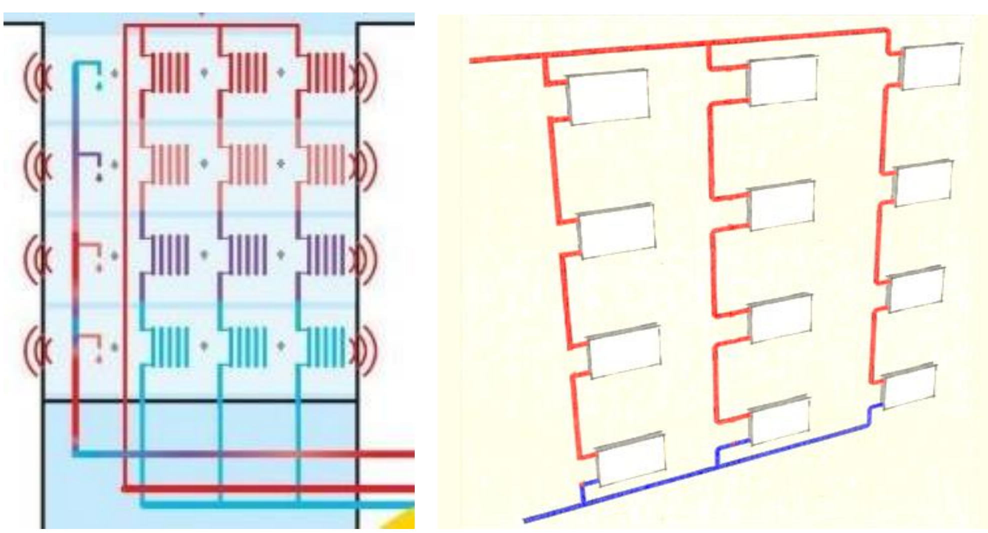

Figure 1 Schematic representation of a vertical heat distribution system

These problems led to the accumulation of huge consumer debt to the supplier of heat, led to the disconnection of individual consumers inside buildings, heated by the CHSS, as well as entire buildings at all.

The problem of the inability to regulate the heat consumed, the accurate and fair knowledge of individual consumption and the low quality of heat that reaches each consumer are now one of the most important in the housing and utilities sector, and all centralized heating systems in Moldova and other countries where presently the living buildings are equipped with a vertical heating system.


These problems need to be addressed quickly, effectively and economically for the majority of the population, especially given the low financial capacity of the population.

One of the solutions, which is currently being introduced by the CHSS in Chisinau is Termoelectrica SA, is the introduction of a parallel distribution system. This solution is rather problematic because it involves complex work and re-connection of all batteries (radiators) in each apartment and also high costs. On average, this amounts to 1200 euros per apartment

https://www.termoelectrica.md/ro_RO/dezvoltare/pti-distributia-pe-orizontala/

Proposed solutions. To determine the individual consumption of each consumer of thermal energy, it is necessary to determine what its effect on the heating fluid per each consumer, meaning how much the quality of the heating fluid has changed/decreased (energy content). In particular, it is necessary to determine what part of the thermal energy flowing through each vertical (riser) is absorbed by each consumer situated on each floor fed by this vertical. Since we consider that the amount of water (mass / volume) is the same along the entire length of the vertical, meaning the systems does not have leakages or selection of the heating fluid inside the building, and the coolant is the same (water!) Along the entire vertical (riser), so the only parameter that changes is the temperature of the thermal carrier from one floor to the next, thereby from one consumer to another, this means that the effect should be measured is temperature changing.

In this case, the temperature values for the entrance and exit from a floor/level are important on each floor. For simplicity, consider the outlet temperature from floor i, equal to the input temperature on floor i-1 (in vertical systems, heat supply where the supply goes from top to bottom, therefore from the upper to the lower floor).

Thus, having a vertical (riser) with a supply from the top to the bottom which supplies heat to n floors and n consumers, thermal data for n + 1 vertical points, i.e., inlet temperatures on each floor (equal to the outlet temperature from the previous floor) will be required, plus one temperature from the exit from the last apartment, which crosses and feeds the corresponding vertical.

The temperature sensor must be on the consumer's segment, that is, on its floor closest to the entrance, in order to minimize inter-apartment losses, that is, as close as possible to the ceiling of the room.

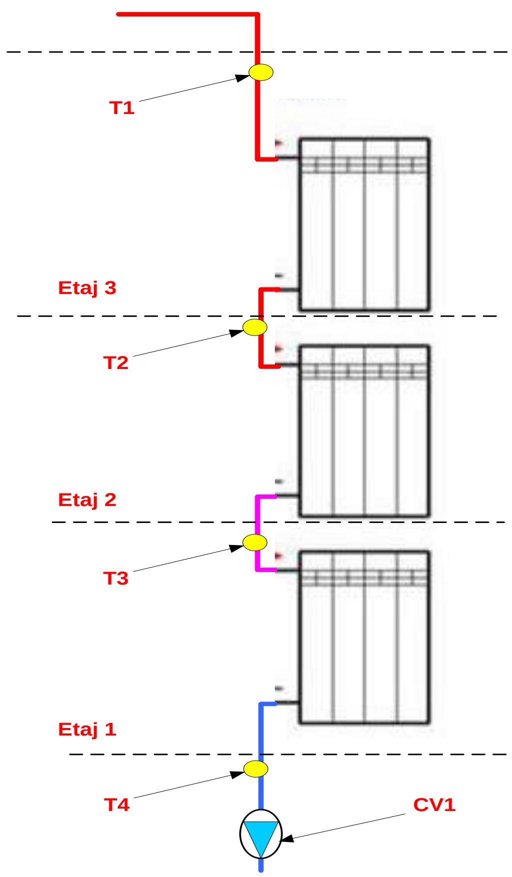

Figure 2 Thermal vertical (riser) and points of collection of water temperature (3 floors)

With yellow, the points from which the coolant temperature should be collected, the points under the ceiling as close as possible to the entrance of the vertical into the heated room (apartment) are indicated.

Having the temperature of the heat carrier (water) for each vertical entry point to the floor for each consumer plus one point for the outlet temperature (see T4), we will be able to determine the temperature differences for each consumer. In this way:

ΔT1=T1-T2; ΔT2=T2-T3 ..... in general $\mathbf{\Delta ti = T_i - T_{(i+1)}}$

Note that T2 is the temperature of the coolant inlet to the next floor, but at the same time, this is also considered the exit temperature from the previous floor.

For the last n-th user, we have: $\mathbf{\Delta Tn = Tn - T_{(n+1)}}$ in the case from figure we have ΔT3=T3-T4

To facilitate calculations, the numbering of temperatures can be the same as the numbering of floors, thus **Δti** which will correspond to the ***i***-th floor of the building. (with appropriate corrections in the calculation of temperature differences)

At points of intersection of the heating vertical (riser) with the floor, a thermal cell (a cell of heat consumption) is formed, in the case of the presented figure there will be a vertical with 3 cells of heat consumption.

In the case of a building with n floors and m verticals, we get ***n*m*** cells of heat consumption.

For example, a 5-storey building and 20 verticals form ***5*20=100*** cells of heat consumption.

Each vertical will also be equipped with a digital water meter (CV1), which will measure the volume of the vertically passing coolant (water).

For a building with several verticals, we will have the situation, as in the picture below.

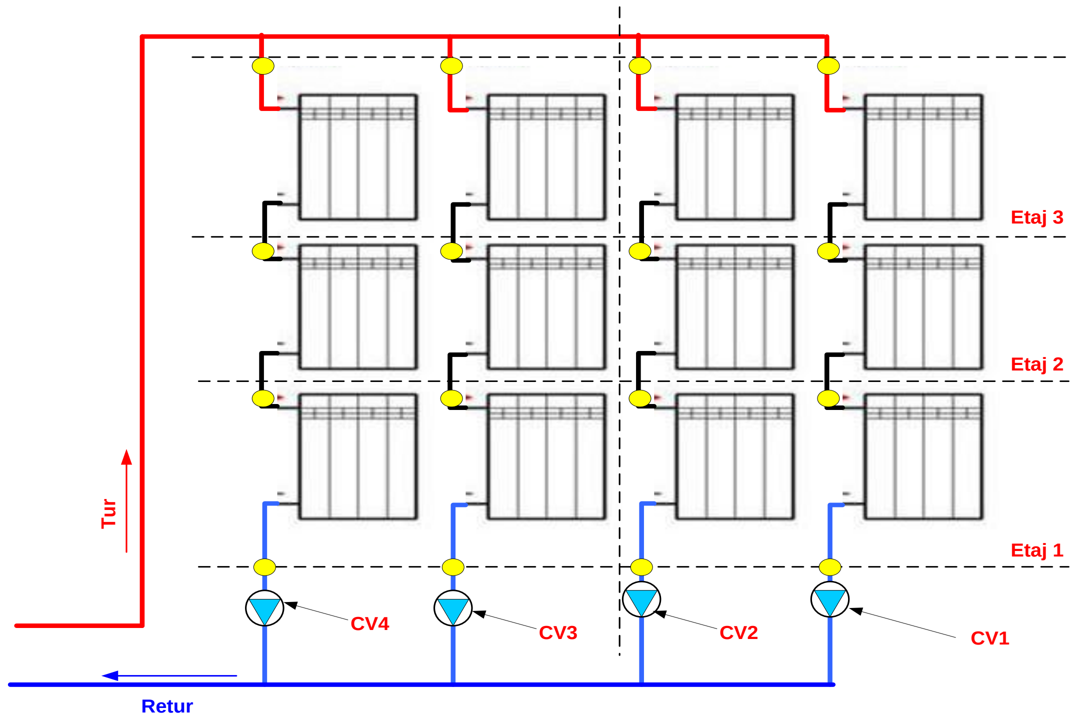

Figure 4 Schematic representation of a building with n heating verticals.

Thus, for a building in the figure above, where we have 3 floors and 4 verticals (risers), we will have 12 cells of heat consumption (energy consumption).

Denote each cell with **Cij** where ***i*** is the floor and ***j*** is the number of the vertical (column).

The temperature drop **(ΔTi)** for each consumer will depend on the surface of the radiator (the number of its elements), the thermal insulation of the apartment, the temperature of the outside air, etc. Thus, all relevant elements are taken into account.

The total heat consumption in the building is the amount of individual consumption of each apartment (consumer) plus total losses due to uninsulated pipes in basements and technical floors of the building.

For buildings that have a common heat meter(majority in Chisinau), you can write

$$Q_{Tot} = \sum_{\substack{i=1 \\ j=1}}^{\substack{n \\ m}} Q_{ij} + \Delta P_{com}$$

Where **Qtot** is the total heat consumption for the building

Qij-heat consumption in cell **Cij** (i-th floor and j-th vertical)

ΔPcom-heat losses in places of common use

Accounting for consumption of each consumer will be based on the summation of heat for consumption cells, from which the apartment is formed (heated space). It can be one cell of consumption per apartment or ***n*** cells, where n = number of rooms + 1 (for kitchen).

Since the apartments consist of cells located on the same floor, for example for a 2-room apartment on the 3rd floor and heated by verticals 1, 2 and 3, the estimated heat consumption will be:

$$Q_{ap12} = Q_{3,1} + Q_{3,2} + Q_{3,3}$$

The consumption of heat for each consumer cell will be determined based on the temperature drop in on the cell and the volume of the transmitted heat carrier along this vertical

$$Q_{i,j} = \Delta T_{ij} \cdot V_j \cdot c \cdot \rho$$

Where Qij is the cell consumption of Cij

ΔT_{ij}-temperature drop for a given cell

V_j- volume of water (coolant) passing through the corresponding vertical

c-specific heat of water = 4187J / (kg * K)

ρ-density of water 1000 kg / m3

The temperature drop for each cell will be taken from the corresponding points T1, T2, Ti, Tn, Tn + 1

$$\Delta T_{ij} = T_i - T_{i+1}$$

For correct operation of the calculation system, these temperatures and water volumes should be read at a frequency of 1-2 times per hour (or more often). Thus, we will have a hourly graph of temperature (per cell) and volumes passing through each vertical.

This can be done with modern digital and telemetry systems that offer solutions for data collection and digitization. Thus, digital temperature sensors are already available on the market and can be installed inside a vertical pipe, the cost of such a thermal sensor is about 3 euros.

Data decomposed by time series is easily processed and can be entered in Excel formulas to calculate the consumption of each apartment in an apartment building.

Below is an example of calculation for several verticals of a 9-storey building, where the temperatures of each vertical entering the apartment are indicated, and below is the output temperature from the last apartment and also the volume of water passing through the vertical counted by each counter/meter.

Table 1 Calculation data for a residential building (example)

Verticals	Vertical 1	Vertical 2	Vertical 3	Vertical i	Vertical i+1	Vertical n
Floors	Temp ºC	Temp ºC	Temp ºC	Temp ºC	Temp ºC	Temp ºC
Floor 9	Apartment 23		Apartment 35			Apart 51
	82	81	80	80	80	81
Floor 8	Apartment 24		Apartment 36			Apart 52
	76	75	75	74	75	75
Floor 7	Apartment 25		Apartment 37			Apart 53
	71	70	70	70	69	71
Floor 6	Apartment 26		Apartment 38			Apart 54
	64	63	65	64	65	65
Floor 5	Apartment 27		Apartment 39			Apart 55
	59	58	58	59	59	61

Floor 4	Apartment 28		Apartment 40			Apart 56
	53	52	53	54	53	57
Floor 3	Apartment 29		Apartment 41			Apart 57
	50	48	48	48	49	52
Floor 2	Apartment 30		Apartment 42			Apart 58
	45	46	45	44	43	48
Floor 1	Apartment 31		Apartment 43			Apart 59
	39	39	40	41	40	46
Temp. Exit point ºC	34	33	34	35	35	40
Volume m3	1,25	1,31	1,82	1,55	1,48	1,84

Data is processed, and we receive heat consumption for each consumer cell

Verticals	Vertical 1	Vertical 2	Vertical 3	Vertical i	Vertical i+1	Vertical n
Floors	Heat Cons in Gcal	Heat Cons in Gcal	Heat Cons in Gcal	Heat Cons in Gcal	Heat Cons in Gcal	Heat Cons in Gcal
Floor 9	Apartment 23		Apartment 35			Apart 51
	0,0075	0,0079	0,0091	0,0093	0,0074	0,0110
Floor 8	Apartment 24		Apartment 36			Apart 52
	0,0063	0,0066	0,0091	0,0062	0,0089	0,0074
Floor 7	Apartment 25		Apartment 37			Apart 53
	0,0088	0,0092	0,0091	0,0093	0,0059	0,0110
Floor 6	Apartment 26		Apartment 38			Apart 54
	0,0063	0,0066	0,0127	0,0078	0,0089	0,0074
Floor 5	Apartment 27		Apartment 39			Apart 55
	0,0075	0,0079	0,0091	0,0078	0,0089	0,0074
Floor 4	Apartment 28		Apartment 40			Apart 56
	0,0038	0,0052	0,0091	0,0093	0,0059	0,0092
Floor 3	Apartment 29		Apartment 41			Apart 57
	0,0063	0,0026	0,0055	0,0062	0,0089	0,0074
Floor 2	Apartment 30		Apartment 42			Apart 58
	0,0075	0,0092	0,0091	0,0047	0,0044	0,0037
Floor 1	Apartment 31		Apartment 43			Apart 59
	0,0063	0,0079	0,0109	0,0093	0,0074	0,0110

Thus, the problem of individual heat metering for each consumer is solved.

Individual consumption control in vertical heating distribution systems.

Under current conditions, the regulation of heat consumption per consumption cell (according to the consumer) is practically impossible, because if one of the consumers reduces the heat carrier flow through its vertical sector, it affects all consumers in this vertical.

The only solution offered to date by the supplier is the transition to a parallel system for the distribution of thermal energy.

In order to avoid the transition to a parallel distribution system that requires high costs and capital reconstruction, a parallel-serial (PSS) system is proposed, which avoids these inconveniences.

In parallel series system consists of the installation in each cell of heat consumption (in each vertical and each floor) along the branch pipe to the radiator, which operates as a bypass, i.e. for shunting the radiator with a special valve (three-way valve) which is installed at the entrance to the radiator, will allow to pass through it a part of the volume from 0 to the total volume passing through the riser.

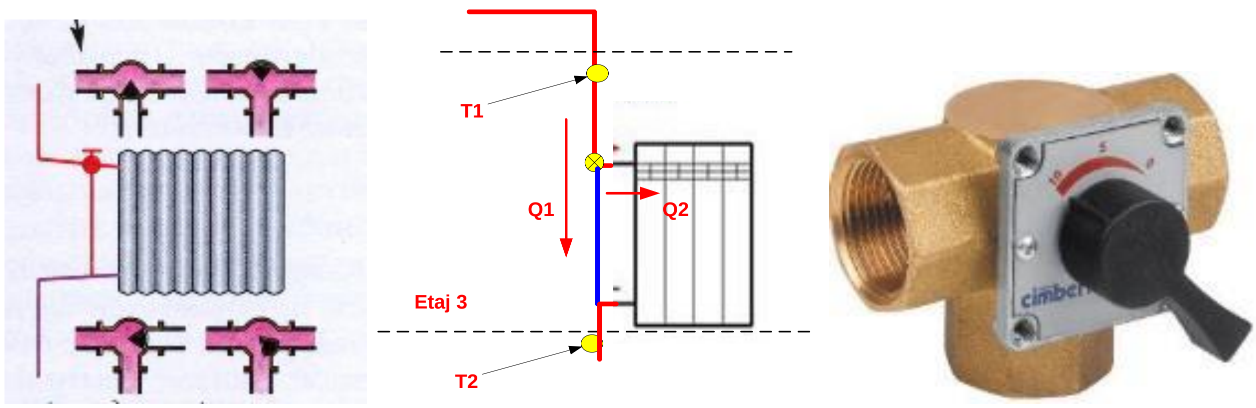

Figure 5. Diagram of regulator with bypass valve

Such an easy-to-use design allows you to set the heat flow Q2 for which passes through the radiator at each moment of time. Adjusting this way, we avoid overheating radiators and excessive heating of the upper floors. In combination with temperature sensors to measure temperature differences on each floor, each consumer will be interested in regulation, as this will reduce losses when ineffectiveness and will allow individual adjustment of consumption.

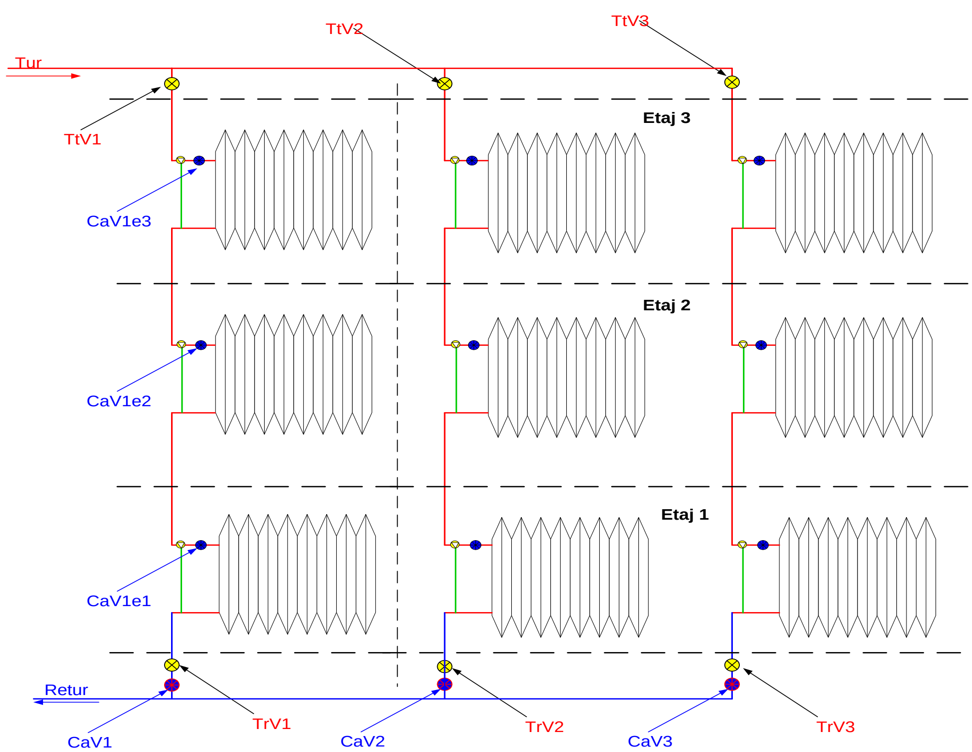

Figure 6. Example of a combined measuring system and bypass pipelines

Economic aspects. At present, the level of technical development allows implementing telemetry solutions (remote measurement) with data storage and automatic processing of data sets obtained under economically viable conditions. In the international market, there are many companies offering solutions, and digital sensors e can be found at prices ranging from 3 to 10 euros, and a water meter with digitization - from 12 to 20 euros, which makes the introduction of such a system very beneficial for each apartment.

An additional aspect is that for each vertical a pressure balancing valve (about 15 euros) must be installed to ensure a normal distribution under any conditions of consumption.

Conclusions.

The introduction of a parallel-series system with an energy consumption accounting system based on heating liquid (water) temperatures at different points in the vertical allows solving the main problems and inconveniences of a centralized heating system. Allows consumers to customize individual consumption of heat energy to each apartment and each individual room, without affecting other consumers, and knowing their exact heat consumption.

After implementation, this system will encourage consumers to increase the energy efficiency of their apartments through insulation, window changes, ventilation, which will lead to a reduction in consumption and lead to a reduction in greenhouse gas emissions.

Useful links.

1. Report on the National Energy Policy http://energyeficiency.clima.md/public/files/publication/Raport_privind_politicile_nationale_energetice.pdf
2. Investments in heating networkshttps://www.termoelectrica.md/ro_RO/dezvoltare/imbunatatirea-eficientei-sacet/
3. Statistics of consumption of thermal energy http://www.statistica.md/category.php?l=ro&idc=128&
4. https://www.diva-portal.org/smash/get/diva2:926925/FULLTEXT01.pdf
5. https://www.ovoenergy.com/guides/energy-guides/ultimate-guide-to-being-efficient-with-heating-and-hot-water.html
6. Good practices example https://www.termoelectrica.md/wp-content/uploads/2016/12/EXEMPLE-DE-BUNE-PRACTICI-v1.22.pdf
7. Digital counters and thermocouples https://www.alibaba.com/product-detail/GSM-SMS-wireless-remote-control-reading_60735369897.html?spm=a2700.7724838.2017115.300.383963e3VxYFKn

https://www.alibaba.com/product-detail/GPT-Armored-Thermocouple-Temperature-Sensor-For_60739671223.html?spm=a2700.7724838.2017115.103.37eb1eceM2IQc3

8. Digital thermocouples, telemetry companies http://www.analog.com/en/products/sensors/temperature-sensor-control-devices/digital-temperature-sensors.html
9. Orange Moldova and the Chisinau Apa Canal have implemented the smart water metering http://unimedia.info/stiri/orange---operatorul-1-care-ofera-solutii-inteligente-pentru-un-oras-smart-149297.html