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Operations, Administration, Maintenance and Automation of Edge Data Centers

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OVERVIEW

As 5G expands and new applications and devices demand large amounts of instantaneous data, the need for locating computing near data will lead to the expansion of Edge Data Centers (EDC). Many of these edge data centers will be located in remote sites with difficult access, like a small fixture on a light post or a small installation in a parking lot, which will present operational, administration, and maintenance challenges due to the lack of nearby maintenance and operations personnel.

In this article we offer a high-level view of operations, administration, maintenance and automation activities for the Edge Data Centers and outline the potential impact new technologies can have to support EDCs in more efficient way.

I. OPERATIONS

Definition of EDC Operations

Data center operations refer to the all the workflow and processes that are performed within a data center. This includes computing and non-computing processes that are specific to a data center facility or data center environment. Data center operations include all automated and manual processes essential to keep the site operational.

Typically, data center operations are distributed across several categories including:

- **Infrastructure Operations:** Installing, maintaining, monitoring, patching and updating server, storage, and network resources;

- **Security:** Processes, tools and technologies that ensure physical and logical security in the data center premises;

- **Power and Cooling:** All processes that ensure enough power is supplied to the data center facility and the cooling system is operational; and

- **Management:** Creation, enforcement and monitoring of policies and procedures within data center processes.

Comparison of EDC and Traditional Data Center Operations

The standard Data Center (DC) operations definition from Technopedia can also be applied to EDC. Below in table one, we have highlighted EDC operations which may be different compared to the traditional DC. This is not a comprehensive list of all operations in an EDC.

Table 1: Differentiated EDC Operations

Category	EDC	Traditional DC	Notes
Rapid Response	DC Operations staff available with slow or average speed of reaction	With the operations personnel available with fast reaction	Every conventional DC assumes there are operations personnel available (like NOC, Infrastructure technicians), while EDC in most cases will have no personal. Therefore, EDC requirements for administration, automation and maintenance will differ from conventional EDCs.
Project Management and Maintenance	Covering multiple locations	Covering single or few locations	Project management for EDCs will differ, requiring much more effort in the initial stage, however during operating phase maintenance of multiple locations can be centralized.
Deployment	Quick deployment	Long deployment	The market trends in prefabricated modules and blocks mean EDCs can be deployed more quickly than traditional DCs
Resiliency	New methods	Resilient, tiered infrastructure	EDC redundancy can be achieved by parallel work of other EDCs. While the traditional DC is much more critical to a failure of any subsystem. Capacity of the EDC sites must be designed in a way to support a failure of one or several nodes.
System Level Testing	Allows factory-based testing	Defined site-based testing procedures and operations	Efficient factory testing reduces costs and complexity of EDC delivery, compared to traditional DCs.
Design	Must be designed in a way that no personnel are available	Some operations may still stay manual, because personnel are available	The trend for EDCs is to have self-operating, highly automated centers, without humans being involved. This can lead to higher availability of an automated EDC network.
Operations Center	Predictive analytics helps identify failures and AI can take some responsibility of the reaction	Human interaction augmented with AI systems	While traditionally DCs rely on human's operating, EDC's may rely on artificial intelligence and less human involvement. Uniformity in EDC hardware will enable less time to repair (MTTR as the number of locations scale up).
Monitoring Infrastructure	Modular service-oriented software and API enabled hardware and Cloud based analytics standardize more and smarter monitoring	Traditional monitoring – taking advantage of distributed service-oriented monitoring/ management systems developed for EDCs	EDCs assume that most components are monitored, such as: UPS, HVAC's, electrical panels, power sources, batteries, etc. through a single interface which might likely be DCIM or DCMaaS (cloud service). AI makes decision – to turn-off EDCs and switch the load to another EDC.
Service Level Management	New service level standards need to be defined	Service level standards applied, like power availability, environmental (temperature, humidity), security, connectivity, response time etc.	Conventional DCs provide SLA (service level agreement) which establishes clear performance standards and quantifiable damages in the event of a service level failure. For EDCs, new SLA KPIs need to be defined, because of the new services that will be offered.
Safety and Crisis Management	Applied to a remote single object or chain of objects	Applied to a single facility with staff available	Security and crisis management planning is different as EDCs are remote facilities without permanent staff. Each object will require separate attention and regulation. In general, the security and crisis management will be required to be more thorough.

Category	EDC	Traditional DC	Notes
Patching and Updating of Monitoring and Management Servers	Cloud based systems	There is still a possibility to use local systems	EDCs don't always assume the possibility to get access to the equipment directly, so cloud-based systems are preferred.
Physical Security Management	Security dashboards integrated with operational dashboards	Security and operations (infrastructure, hardware, network) separate dashboards	Physical security of EDCs will be built into services and APIs (fog-based computing model). Multiple EDCs will have single infrastructure operation centers, which will monitor everything including power, cooling, security, environment etc.
Internal Cabling Installation and Management	Pre-installed cabling, less complex structure, preferably with automation functions (similar to Basic topology from TIA-942)	More complex structure	EDCs in smaller locations will have less complex IT network cabling, but multiple numbers of these locations together with outside cabling makes overall administration as complex as in a conventional DC.
Outside Cabling Installation, Maintenance and Management	Outside cabling is more complex	Less complex structure	More diversified outside cabling, with multiple connections: EDC to EDC, EDC to Aggregation/Core, will require intuitive and clear documentation.
Organization and Staff Management	Multi-skilled staff capable in performing various tasks. Three levels of staff based on skills are: • Professional (1) • Specialized (2) • Expert (3)	Different experts in their field of expertise	In a conventional DC there are dedicated people responsible for various subsystems (like electrical, mechanical, network, cabling etc. engineers). EDC technicians must be multi-functional and perform various tasks, therefore system management must be intuitive and clearly documented. Standardization of equipment is important to reduce time for repair.
Administrating the Infrastructure	Depending on applications, only some EDC infrastructures could be managed	Majority of infrastructure is managed	EDC Administration will depend on the integrated ecosystem of partners that can manage the EDC proactively or dynamically depending on the level of EDC Automation.
Maintenance	Multiple locations	Single or several locations	In conventional DC there is always maintenance work team 24/7 available, EDC can't be visited promptly, because there are many of EDC and few technicians.
Automation	Higher level of automation	Still some processes can be performed manually	Quantity, geographical spread and lack of prompt assistance will lead EDC to be semi- or full automated. In conventional DC still many processes run manually, like testing fault tolerance, inventory management, patching telecommunication cables etc.

Other disciplines

Other disciplines defining EDC operations will be similar or slightly different than traditional DCs. The DCOS (Data Center Operations Standard) prepared by data center professionals and by the leadership of EPI (www.epi-ap.com) defines service, maintenance and operation requirements for data centers to have a consistent level of quality. The methodology set out in the DCOS standard can be applied to describe operations in EDCs as well. Methodology will be studied more closely in the future when working out the TIA-942 addendum.

Maturity levels

The sophistication of operations, procedures and processes are running in EDCs or EDC networks determines the maturity level of EDCs. The classification of maturity levels is provided in the DCOS ®(Data Center Operations Standard) by EPI.

Figure 1: DCOS (Data Center Operations Standard) (Courtesy of EPI)

Because the EDC is unmanned, the Edge Data center working group at this time recommends that EDCs have at least DCOS-3 level of maturity. The characteristics of DCOS-3 and above are outlined below:

- **DCOS-3:** Processes are defined and documented at the high level. Procedures might not be described in detail leading to interpretation of the individual, therefore some deviations might occur during execution of these processes. Documents are available and have some level of document management control. Training is more formal but might be generic for all. Monitoring is used in its basic form to support some of the processes. A critical distinction between DCOS-2 and DCOS-3 is that processes are described, and processes are managed more proactively.

- **DCOS-4:** Processes are clearly defined and provide predictable process performance. The defined processes clearly state the purpose, inputs, entry criteria, activities, roles, measures, verification steps, outputs, and exit criteria. Staff have been trained on the processes and sub processes. Processes are monitored and measured for compliance and conformity and action is taken to improve the process where processes/procedures appear not to be working effectively. Staff training is pro-active and regular refresh is provided to ensure optimum performance. Monitoring is used to support the processes. A critical distinction between DCOS-3 and DCOS-4 is the predictability of process performance and continuous improvement cycle.

- **DCOS-5:** Processes are closely aligned with the business strategy. The organization continually improves its processes based on business objectives and performance needs by continually improving process performance through incremental and innovative process and technological improvements. Staff training is well planned and proactive, a regular refresh is provided to ensure optimum performance. Monitoring is used at an integrated level to support the overall business. A critical distinction between DCOS-4 and DCOS-5 is the focus on managing and improving organizational performance.

II. ADMINISTRATION

The EDC will be mostly unmanned, so it is important to understand how the administration of EDCs will be performed. EDCs will be managed by an integrated ecosystem of partners (see figure 2 below). A robust and efficient infrastructure administration is mandatory to support the geographic scale and scope of EDC networks.

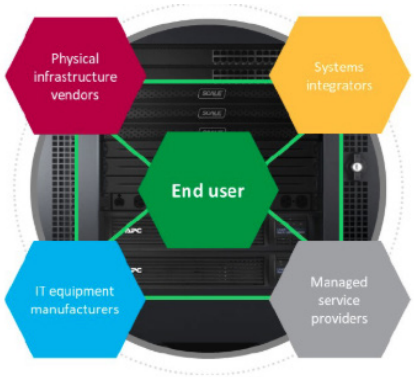

Figure 2: EDC Management and Administration (Courtesy of Schneider Electric)

In order to ensure that the communication processes between different partners working together in the same ecosystem is successful, the administration of the documentation and processes between these partners is very important.

We can define four management levels depending on how mature the ecosystem for an EDC is, outlined below:

- **Level 1. Reactive: Incident Management:** This is the starting point for most data center implementations. IT staff are principally trying to survive day-to-day crisis and what few management tools are employed are generally device-specific rather than enterprise-class. At this level, organizations should focus on process improvements for improved administrative efficiency and cost effectiveness. Begin with an identification of all assets in the infrastructure along with their dependencies and performance status. These details should be stored in a centralized repository that is continuously updated to enable an accurate and holistic view of the environment. Processes for regular system maintenance and problem remediations should also be established and documented with clearly defined roles for both facilities and operational IT support staff.

- **Level 2. Active: Process Management:** Although day-to-day operational issues are still the primary focus in this phase, some processes are documented and repeatable, enabling some automation to be introduced. Standardized processes should be combined into logically organized workflows, and a change management process must be established to ensure updates and new implementations are properly authorized and tracked. Data center control and access restrictions should be adopted to minimize incidents of unauthorized use and inappropriate changes. Energy consumption and thermal conditions should be recorded and included in a centralized report. It should be noted that some processes in Level 2 can be implemented in Level 1 (and vice versa), but all services should be established before proceeding to Level 3.

- **Level 3. Proactive: Problem Management:** In a Level 3 environment problems are more easily remediated with procedures in place for root cause identification. Proactive problem prevention is a primary focus; management solutions are selected strategically, rather than reactively. A holistic view of the infrastructure should be available and can be visually modeled to enable informed decision-making on environment improvements. Energy reduction programs can be introduced that will significantly reduce operational expenses. Capacity planning also becomes more proactive at this stage as future growth is anticipated and new acquisitions are identified for their long-term business value.

- **Level 4. Dynamic: Infrastructure Management:** At the most mature stage in pragmatic data center management, day-to-day performance and availability issues are largely managed by automation, so IT operations can focus on meeting evolving business requirements. A “closed loop” infrastructure control system ensures issues are proactively identified on both physical and virtual platforms before becoming business impacting. Governance bodies choose optimal IT solutions and configurations that address the needs of multiple business units and ensure they are implemented cooperatively across the disparate IT support organizations. The primary focus of IT is to ensure the on-going vitality of the business.

III. MAINTENANCE

Highly skilled personnel are required to effectively manage the complexities of a data center. Each area within a data center has resources focused on their own management function. The same set of skills is required to manage EDC however, one team of skilled experts is responsible for supporting multiple EDCs.

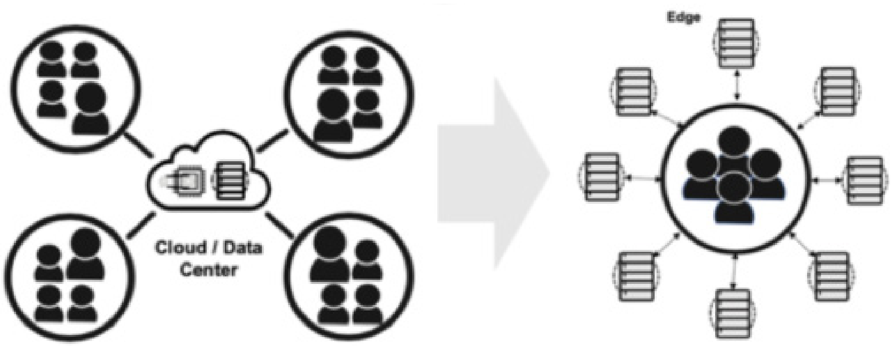

Figure 3. Data Center Organization & Skills > Edge Organization & Skills (Courtesy of RF Code)

Deploying, replacing and repairing IT equipment in thousands of EDCs in edge locations carries a very different set of challenges than doing the same for traditional enterprise data centers.

Edge locations are different. A “truck roll” is an expensive necessity for edge locations. Edge sites are, by definition, distributed throughout a metropolitan region, often located miles apart, sometimes at the end of a dirt road. The logistical challenges of deploying and replacing equipment can be nearly insurmountable.

By deploying standardized sets of equipment in edge locations, EDC owners can benefit from the efficiencies of a pre-defined inventory on a truck or in the local warehouse. This approach would allow for quicker dispatch of a technician with the appropriate material and would provide new efficiencies to remote edge locations.

Predictive Analytics using machine learning techniques will help EDC operators and services teams to predict and anticipate failures in the infrastructure. Adoption of these tools should help to reduce cost of maintenance, reduce downtime and improve reliability.

EDC’s should focus more efforts on preventive maintenance than corrective maintenance. The implementation of management tools like BMS, NMS, Asset Management, DCIM, AIM, etc. are becoming more important to monitor all the systems and give the right information to EDC operators to make decisions about when to schedule the appropriate maintenance.

EDC maintenance should be supported by multiskilled staff. Field service engineers can be categorized as professional, specialized and expert depending on the level of expertise on some specific equipment, however the adoption of VR / AR technologies will help this staff to improve efficiency by having remote support.

In order to maintain all the firmware updated from all different equipment supporting EDCs, operators should follow different standards like ISO 15504, ISO 33004, ISO 12207 and ISO 2000.

IV. AUTOMATION

Data center automation is the process by which routine workflows and processes of a data center—scheduling, monitoring, maintenance, application delivery, and so on—are managed and executed without human administration. Data center automation increases agility and operational efficiency.

Data center automation is primarily delivered through a composite data center automation software solution that provides centralized access to all or most data center resources. For this reason, the automation software should provide heterogeneous multi-vendor support.

Automation should be enabled using an API architecture that allows equipment to be monitored and controlled across a suite of management tools. The integration of the data from various systems would allow for a more intelligent multi-systems solution management.

Autonomous edge data centers require machine learning, which needs input data. An edge data center could be treated as an IoT microcosm, every device and software package could have a sensor or log that feeds data to the application of artificial intelligence (AI), machine learning and automation.

Sensors/Remote Monitoring and Control Capabilities

Power

Automation considerations that could help manage power needs at an EDC include:

- Electrical panels with integrated monitored breakers, power metershe most mature stage in pragmatic data center
- UPS systems with integrated management capability allow critical remote UPS monitoring such as low battery, bad battery, on battery, overload, low runtime, etc.
- Generators systems with integrated monitoring systems for fuel tanks, batteries status, oil temperature, etc.

Environmental

Automation considerations that could help manage environmental operational needs at an EDC include:

- Cabinet level temperature sensors
- Room level temperature sensors, for example, the ones integrated into lighting fixtures
- Leak detectors are the most important when condensate pumps are used for cooling systems These should also be used in cases where the IT racks are near a water source such as a water pipe, or when below grade.
- Air quality sensors
- Cabinet level humidity sensors are used if humidity is trending upward over time, there may be something wrong with the cooling system or a source of moisture entering the room.
- Vibration sensors are helpful for detecting vibration that can cause damage to the circuit boards and other components over time. Monitoring vibration trends can alert management of an otherwise “invisible” threat to IT availability.

Physical Security

Automation considerations that could help physical security operational needs at an EDC include:

- Lighting systems with motion/occupancy sensors
- Dry contact sensors to detect when a rack door or room door is open.
- Biometric access locks to track an identity of those accessing the EDC
- Smoke detection system

- Patch Panel port sensing use AIM systems to detect and report, in real time, any unauthorized changes to the patch cord connectivity. AIM systems can be integrated with security cameras, where present, to activate during unauthorized events and provide access to recorded content.[1]

Network Infrastructure

Automation considerations that could address network infrastructure needs at an EDC include:

- Asset tracking (RFID tags, Beacons, etc.) - to monitor presence and location
- AIM systems enable EDC management personnel to monitor, manage and optimize the connected environment in real time, enhancing the ability to
  - o Plan and execute changes to the connectivity;
  - o Troubleshoot connectivity issues in real time;
  - o Discover and track the location of connected devices; and
  - o Manage and monitor capacity and asset information.[2]

Machine learning is a key technology in driving and accelerating data center automation. Any machine learning engine is only as good as the data that is put into it. Networks need comprehensive visibility tools that provide high-quality data in order to get value out of machine learning engines. All networks are different, so there will be a great deal of baselining and learning that a machine learning algorithm will need to do before it can produce good recommendations, and all of that requires network data, the same data that provides input into network visibility solutions.

Compliance

EDC automation also needs to provide compliance, which includes auditing and reporting of live configurations; comparing current and past configurations to spotlight differences; and implementing rule-based policies for regulatory standards such as the Defense Information Security Agency (DISA), GDPR, Health Insurance Portability and Accountability Act of 1996 (HIPAA), etc.

Examples of Using ML/AI for EDC Automation:

- **Equipment Maintenance:** Statistical algorithms and AI-driven machine learning can monitor every system in an EDC and identify potential problems before they develop. When simulations and analysis in EDCs find that a system is likely to fail within the next few months, it can be replaced more quickly and efficiently, rather than suddenly failing and compromising data center performance.

- **Fallover Management:** When integrated with other smart data centers as part of a larger network, unmanned facilities can shift into maintenance mode when something goes wrong and offload processes to other data centers until technicians can address problems.

- **Energy Management:** Power and cooling requirements can fluctuate rapidly based on usage needs. Automated tasks and systems informed by predictive analytics that monitor usage trends over time and model future demands for optimal power consumption, which can reduce energy costs and improve overall system reliability.

- **Incident Management:** One of the most time-consuming tasks for any IT department is dealing with tickets generated by incidents throughout the systems being monitored. In many cases, these tickets don't represent serious issues, but rather temporary errors or minor problems that

[1] ANSI/TIA-5017 Physical Network Security

[2] ANSI/TIA-5048, BICSI 009-2019: Data Center Operations and Maintenance Best Practices

are easily addressed. Rather than taking up hours of a system administrator's time, the process should be automated by using machine learning systems that analyze logs and event records to learn how to regulate and respond to system changes that represent minor problems in real time.

- **Scheduling and Executing Routine Operations:** Many routine data center functions that are vital to keeping the facility running smoothly are rather easy to perform with minimal effort. Data backup, replication, and other application events are just a few processes that can easily be set up as automated tasks and scheduled to be performed regularly. Other repetitive and time-consuming tasks like implementing patches and setting configurations can be addressed through automation.

V. CLOSING THOUGHTS

This article recommends improving the maturity of processes for Edge Data Centers compared to processes for traditional Data Centers due to the lack of qualified personnel on site in most cases.

With the help of automation, monitoring and the systematic application of new technologies, the EDC market will increase the resilience and availability of systems and applications.

OAMA authors have considered that most important KPIs for Benchmarking should be studied and analyzed deeply in order to be included in future articles related to Edge Data Centers.

To learn more about the TIA's Working Group efforts in developing information and standards on Edge Data Centers (EDCs), go to the TIA website: https://www.tiaonline.org. If you have opinions or expertise to lend to this effort, please reach out to edcinfo@tiaonline.org.

APPENDIX

ANSI/TIA-942	Telecommunication Infrastructure Standard for Data Centres
ISA-71.04.2013	Environmental Conditions for Process Measurement and Control Systems
ISO 14001	Environmental management systems
ISO 14644	Cleanrooms and associated controlled environments classification of air cleanliness
ISO/IEC 20000	Information technology -- Service management
ISO 22301	Societal security – Business continuity management systems – Requirements
ISO/IEC 27001	Information technology – Security techniques – Information security management systems -- Requirements
ISO/IEC 27002	Information technology – Security techniques – Code of practice for information security management
ISO 31000	Risk management -- Principles and guidelines
ISO/IEC 38500	Information technology -- Governance of IT for the organisation
OHSAS 18001	Occupational Health and Safety Management Systems
DCOS	Data Center Operations Standard

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