Benefits
of
IoT Applications
in
RF-Systems

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Content

1 Scope

Broadcast services for Radio and TV distribution is a well-known technology and used since more than 100 years to reach efficiently and conveniently a large numbers of consumers. After a long period of no innovation, broadcasting got new impulse through digitization and related new features and higher quality Radio and TV standards.

Figure 1: Typical broadcast towers

A transmitting tower for TV and Radio broadcasting is a complex “ecosystem” made of electronics and metal components. Among these parts, antennas, power splitters, cables, filter/combiners and transmitters are the most important (and delicate) ones.

A typical rf-system has **indoor and outdoor** components. The major indoor components are the following:

- Power amplifiers
- Combiners/filters (in case several channels share the antenna distribution system)
- Patch panel
- Feeder connection (main cable or rigid lines)
- Caox cable/rigid lines

The major outdoor components, installed in the tower, are the following:

- Cable (up to several 100’000 Watt, feeder and distribution cables/rigid lines)
- Connectors (up to 8” size depending on the transmission power)
- Power splitters/dividers (one power signal from the transmitter is divided several times to serve several radial organized antennas (2-5 depending on required area coverage)
- Antennas (the antennas are mounted for radial transmission on several levels/bay with different tilt)

A tower is hosting several systems for analog and digital radio and TV channels in different frequency bands (up to 100 antennas in one tower). The size of the rf-system and its technology is largely dependent on the radiation pattern chosen by the operators, considering the topology and number of inhabitants served in the targeted region.

2 Broadcast Industry Challenges

In the last century, monitoring was not a major issue because of little competition, enough skilled resources and vertical industry structures/state monopoly.
In the 1990 decade, in developed countries, cable TV has been installed in urban and suburban areas and satellite service started to be a mainstream technology. In the new century the IP revolution and digital TV over cable/Internet became very popular in developed countries, however these technology evolutions and its economics is largely dependent **on population density**, **wealth** and **geographical size/topology** of the countries. Still the terrestrial broadcasting technology is the main provider of Radio and TV services in the world.

However, the **cost pressure** on the broadcast tower operators is increasing because of:

- Increased competition (market liberalization, new technologies)
- Age of the infrastructure and higher probability of failures
- Higher labour costs (smaller and central operation teams)
- Limited access to skilled people (out-sourcing)
- High penalties in Service Level Agreements

These changing factors drive the operators to further increase the quality of the broadcast service, drive the maintenance and operation costs down, as well as optimizing income from tower real estate investment (co-location).

Another driving factor is the new allocation of engagement within the value chain of vertical organize operators. The impact of the changing environment forces operators to either outsource operation or share service or tower infrastructure with other parties (co-location).

3 Today's Monitoring Technologies

Current products and technologies **focus on indoor and single point of measurement** applications. Well-established vendors offer modified traditional directional couplers to measure average rf-power in forward and return direction, to determine VSWR/Return Loss values.
Typical suppliers of such stand-alone solutions are:

- Bird Technologies
- Broadcast Devices
- TASC Systems

These solutions give **local access** to the data (RS232 interface) or can be connected one by one to a network with an Ethernet interface.

Also the suppliers of Combiners/Filters for broadcast solutions offer directly integrated directional couplers. However, these couplers provide rf-signals with a defined coupling attenuation i.e. 20 to 60 dB, to connect rf-power meters. With special adaptors, these vendors offer the digital reading of these signals and local display, normally built for a low number of couplers to be connected. Typical suppliers of such equipment are:

- RFS
- SIRA
- Com-Tech
- Exir Broadcasting
- Dielectric

Existing systems lack of an end-to-end approach for the operator. They mostly focus on a low number of measurement points optimized for local usage. There is no centralized management system, data are not recorded and there is no possibility to analyse data over a longer period.

4 Issues for the Operator

For the broadcast tower operators, the key issue is that the operation shall be guaranteed 7x24h. No downtime is allowed; otherwise SLA penalties can come into action. **Uptime guarantee and safety** are therefore the main goals.

Broadcast tower operators (operators) own and maintain the overall infrastructure and offer the broadcast service to its customers, the content providers or to collocation partners.

When a problem occurs in the rf-system and the transmission stops or the radiation is reduced, a maintenance team has to reach the tower's site (often located on mountain's peaks) and check the rf-system incl. the antennas that are mounted on the tower. A significant amount of time (and money) is required for this operation, because there is little or no information where the malfunction could be.
Failure recognition can take some time, not only the service is reduced or fails also it could lead to further damage (breaking of seals, cable overheating) or even severe disasters with big fires and destruction (e.g. Moscow, Ostankino or Netherland, Hoogersmilde).

The goal is prevention

An operator survey has shown that estimated 50% of the failures/malfunctions are not happening instantly. Actually, such incidents are caused by gradual degradation of the system, such as water infiltration, mechanical abrasion, slow death from material defects or installation failures (e.g. screws and cable not mounted properly).
Such reasons do not necessarily have to conclude in a rf-system failure. If the quality of the signal is monitored, signal degradation could be discovered and required actions could be taken. Such prevention would greatly reduce downtime of rf-systems and help the operators to ensure 7x24 interrupt free operation. Degradation of system parameters would allow to resolve discovered issues in time, before worse things happen.
This situation results in the following consequences for the operator:

- Doubt over compliance to Service Level Agreements
- Preventive maintenance is time based as unable to measure performance degradation
- Inefficient resource allocation, minimal oversight can elevate material and labour costs
- Increased mobilisation effort, trouble shooting and repair times. Increased health and safety risk
- Increased probability and risk of extended service down time. Potentially days versus hours.
- Risks that maintenance teams may not have the necessary replacement parts on site
- Operator is forced into a more reactive model, this requires extra systems and processes to comply

Conclusion:
Today, it is **virtually impossible to prevent a malfunction** in a rf-system, even worse, once the failure happens, it is impossible to know - remotely or on site - which of the several antennas and splitters are damaged.
There is only one possible path for the resolution of the fault: bringing a team of technician's on site, switching off the transmitting system and let technicians manually check each one of the antennas installed on the tower.

5 Possible Alternatives with IoT Application

Currently the installations in the tower and partially in-house are **not permanently monitored** this results in three effects:

- A malfunction is only detected if it results in partial or total system failure
- If there is a malfunction (no or little radiated signals), the failure location is not known

- No pro-active action can be taken in case of a severe damage in the tower, affecting the power radiation, which could cause fire and further damage (cable, amplifiers)

This situation is a great motivation for an operator to evaluate an IoT system, which is addressing his critical needs:

1. reducing cost of repair / maintenance in case of failure
2. reducing time for recovery in case of failure
3. preventing downtime
4. Increase broadcast tower security
5. remote and real-time monitoring of towers' and filter/combiners performance
6. Offering enrichment (upselling) guarantees of service
7. Clear allocation of failure responsibility in case of collocation

IoT (Internet of Things) term in general is used in this context to bring local information and data onto the Internet, permanently available, on-line and everywhere.
What data could be interesting for an operator to be in control of the rf-system? Here a list of possible candidates:

- Performance data of the rf-signals
- Quality data of the rf-signals
- Environmental data, such as: temperature, humidity, acceleration
- Site information, such as: infrastructure condition – power, people on-site, etc.

From a technology point of view in general an IoT solution has the following components:

- Data collection device: sensor, data reading unit
- Network connectivity unit: wlan (Wi-Fi), mobile data communication, Ethernet
- The Inter- or Intranet as a transport service
- A SW system for the data collection, processing, visualization and control device. This could be an APP or a browser based solution

In contrary to standard IoT applications, monitoring the rf-system has very specific properties. Indoor and outdoor applications are different, not only it is outdoor and very often in remote locations installed; it also has a very rough electrical environment. Several 100 kW of radiation over the frequency band from 50 to 850 MHz for Broadcast and possible co-located other rf-components from Mobile to LMR (Land Mobile Radio) makes it a very challenging task to connect an IoT device to the Internet. Another challenge are the number of measuring point in an outdoor application inside the tower. Not only is there very limited space for cabling, it is also a commercial consideration for a higher number of data collection points. Typically, a bigger tower installation could easily ask for 20 up to 40 measuring points.

Connectivity technology overview:

Connectivity technology	Pro	Contra - Issues
Ethernet	Standard mass market components	Noise immunity? Limited distance
Mobile (GSM, LTE)	Only power cabling required	Noise immunity?, coverage in remote areas, connectivity costs, SIM card handling
wlan	Standard mass market components	Noise immunity?
Fibre	Standard components, noise immunity, galvanic insulation	Costs, robustness
Proprietary	Specific suited and designed solutions	Costs due to limited volume

Table 1: Connectivity technologies

General issues to be considered in such installation are:

- EMC compatibility
- Cabling
- Rough environment
- Robustness
- Electrical (surge) and mechanical protection
- Easy installation
- RF-signals are not influence by sensors or data collection points
- Construction variety of RF-Systems

Looking at all these impacting points in a holistic view, this leads to the result that the best solution is dependent on the number of data collection points in the outdoor situation.
Is the number rather small, we have 2 or 3 measuring points, standard technologies with mobile data connectivity seems a possible way forward. Direct point-to-point cabling (PoE) is feasible, noise concertation is small and wireless technology could work (wlan).
However is the installation bigger (5-50 measuring points), data concentration and power distribution in the tower is necessary. Since the distance between installation and cabinet are often > 100m (i.e. in the USA around 500m), fibre based communication is a good choice with the advantage of galvanic insulation and noise immunity.

The **main system requirements** for an end-to-end IoT solution are:

- None invasive for rf-signals
- High accuracy
- Durable and high MTBF figures
- Suited for in- and outdoor application
- EMC compatible
- Robust outdoor system
- Surge protected against lightning
- Scalable to connect up to 100 measurement points indoor and outdoor
- Easy to install in retrofit and new installation situations
- Possibility to connect existing installed directional couplers
- Possible to make post initial installation enhancements
- Centralized data management
- Alarm management with threshold incident functionality
- Alarm forwarding with SMS, APP, email
- Offering various network connectivity
- Data recording > 3 years
- Browser based local and remote configuration
- SNMP functionality for NMC integration
- Automatic amplifier switch of functionality
- Covering Monitoring points distances up to 600m / 1968 ft

6 Added Value and benefits with IoT in a RF-System

The operators of rf-system are challenged by competition, personal costs, outsourcing and high level service commitments.

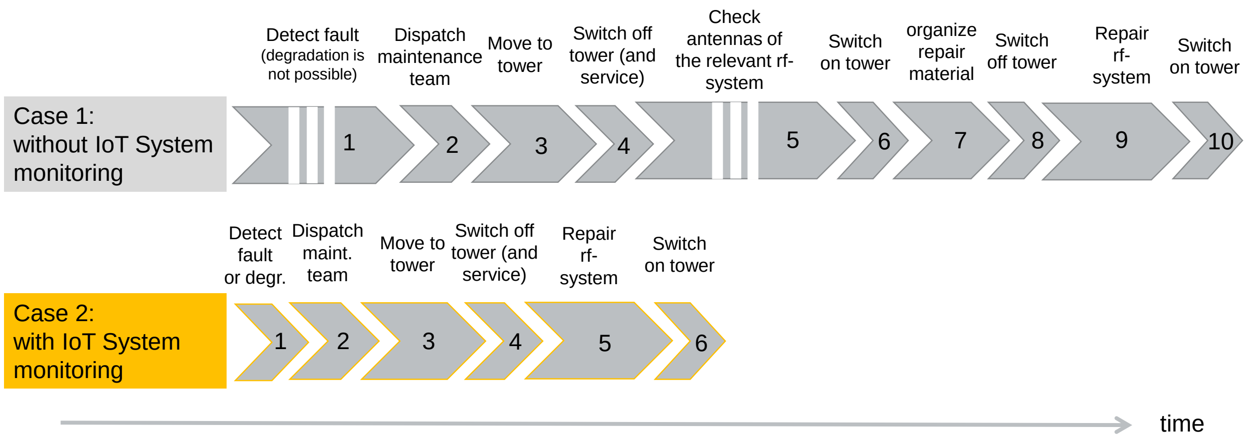
Benefits for the operator with IoT built in his rf-system	**Required IoT functionality**
Do **preventive maintenance** and prevent from partial/total system failures.	Measurement data are logged and a trend curve per data collection point is visible. Defined break point barriers (thresholds) raise an alarm with different severity.
Minimize SLA violation caused by “slow death” effects (like water in the system, mechanical abrasion).	In case of preventive alarm (system degradation), operation can initiate a maintenance task in due time, but controlled and scheduled.
Safe time and cost for failure detection because of direct failure localisation.	The measurement values gives clear indication which path (antenna/cable) is affected. The detailed value of PTx/PRx gives further information if the problem is in the antenna or in the feeder cable. Based on this information also external maintenance teams can be more efficiently controlled.
Safe time and costs to repair because the correct spare material is on site.	Through the direct failure indication, the right spare material (connectors, cables, and antenna) can be provided with the first maintenance action.
Safe fixed costs because of central dispatching and optimized maintenance team assignment.	The operator can dispatch maintenance teams planned because of the degradation information of DAC Sensors and reduce the “emergency” actions costs.

Increase the safety of the broadcast tower, in case of rf-system failure in the tower, the operator can switch of the amplifier (Power, up to several 100 kW).	The IoT solution is monitoring the transmission power. The operator can take pro-active action in case of failure detection, i.e. he can switch of the amplifier.
Support Collocation by monitoring the Service Access Point (SAP) in sharing broadband antenna systems.	The IoT solution is monitoring the point where the responsibilities from either party change. This allows both, the operators and its customer to prove SLA compliance and the reporting requirements.
Qualify outsourced **Operation and Maintenance tasks** by third parties.	With the IoT solution and monitoring, the operator has a high visibility of rf-system function. He is able to qualify work done by the outsourcing partner before and after tasks has been performed.

Table 2: Benefit of IoT system for an operator

6.1 Business Case for the Operator

Comparing a typical incident procedure with and without an IoT System. It becomes clear that with the IoT System the mean time to repair (and with that the service down time) will drastically reduce.



Principle illustration: time blocks are not proportional to the used time, e.g. detect fault in task No. 1 in case 1 could take very long, in case 2 it is immediate. The same issue for task No. 5 in case 1, depending on the size of the tower this task could be over proportional long.

Figure 2: Comparison repair process: with and without IoT System

Based on first IoT installations and initial feedback of broadcast operators the costs benefit with an IoT System has been calculated. To make the cost comparable for different operators and different cost levels, relative figures (%) are presented. The two main cost blocks considered are:

- Operation costs → act on incidents, failure, malfunctions, degradation issues, etc.
- Maintenance costs → tower inspections, preventive maintenance (optical and electrical tower inspections)

The following table gives an overview on the **main costs blocks** related to an IoT Monitoring System, its benefit and impact for the operator.

Operator cost blocks	Added Value IoT System Benefit to the tower operator	IoT System features required
SLA violation	Minimize SLA violation caused by “slow death” effects (like water in the system, mechanical abrasion).	In case of rf-system degradation, the IoT System can escalates an alarm. The operator can repair the rf-system **before a total failure** occurs.
Operation costs	Reduce maintenance costs and time to repair by 50%. Depending of the number of relevant failures, the operator can save millions per year.	Through the direct failure indication of the IoT System: • the right spare material (connectors, cables, and antenna) can be provided with the first maintenance action. • Long failure search are eliminated. • External repair teams can be better controlled.
Maintenance costs	Normally operators perform frequent tower inspections every year or every second year. These inspections can be either totally eliminated or reduced (no tower climbing required anymore). Depending of the number of towers, the operator can save millions per year.	In case the rf-system performance **degrades** or a total failure occurs, the IoT System immediately raise an alarm. This makes regular maintenance visits obsolete.

Table 3: Operator cost blocks influenced by an IoT System

The cost saving calculation includes the depreciation of a typical IoT System, but does not include penalties or fees through Service Level Agreement (SLA) violation (reduced performance, service interrupt).

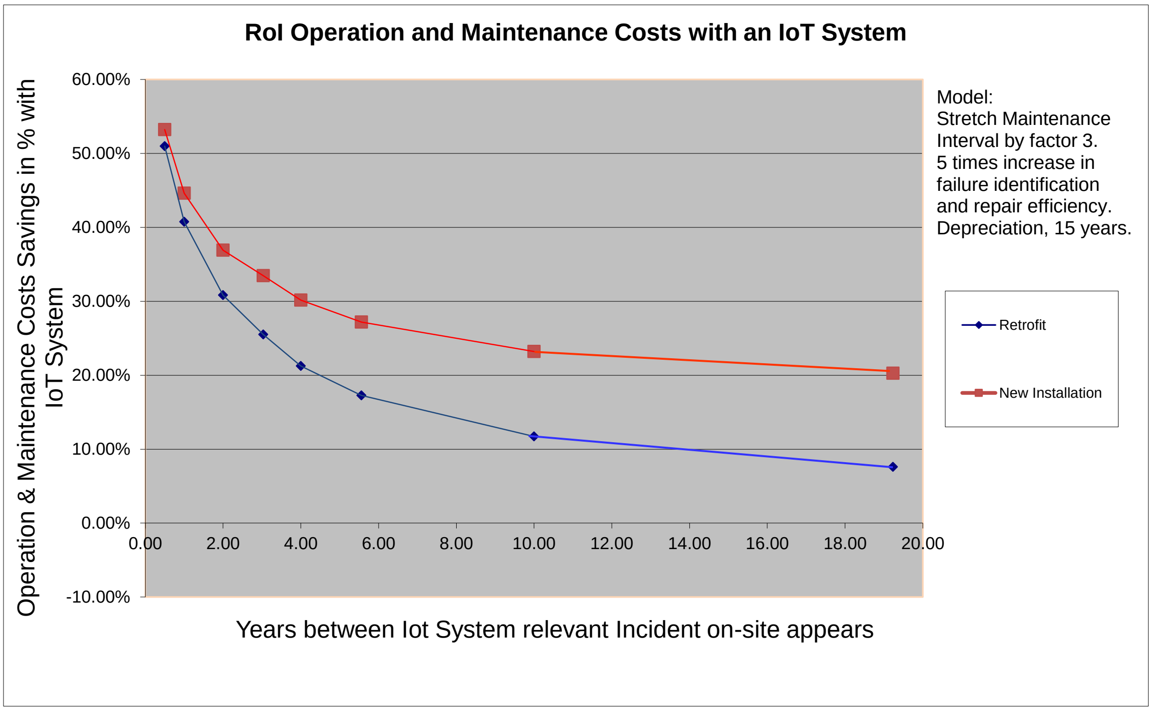


Figure 3: Cost benefit with an IoT System

Conclusion: The model calculation show, that **in any case the operator has a cost benefit** with an IoT Monitoring System. The benefit is largely dependent on the number of incidents appearing in the network. It is also visible that in case of “New Installations” the benefit is bigger because the installation costs are very small (data collection points are pre-installed before antenna installation).

7 Future and Outlook for IoT in RF-Systems

IoT offers the possibilities to connect and collect further important data in an outdoor tower installation. Beside RF performance parameters, the infrastructure of the tower could be monitored in more detail:

- the status of the navigational lights could be monitored
- it is possible to collect detailed environmental data and correlate them with the performance data
- measure the physical stress of the construction

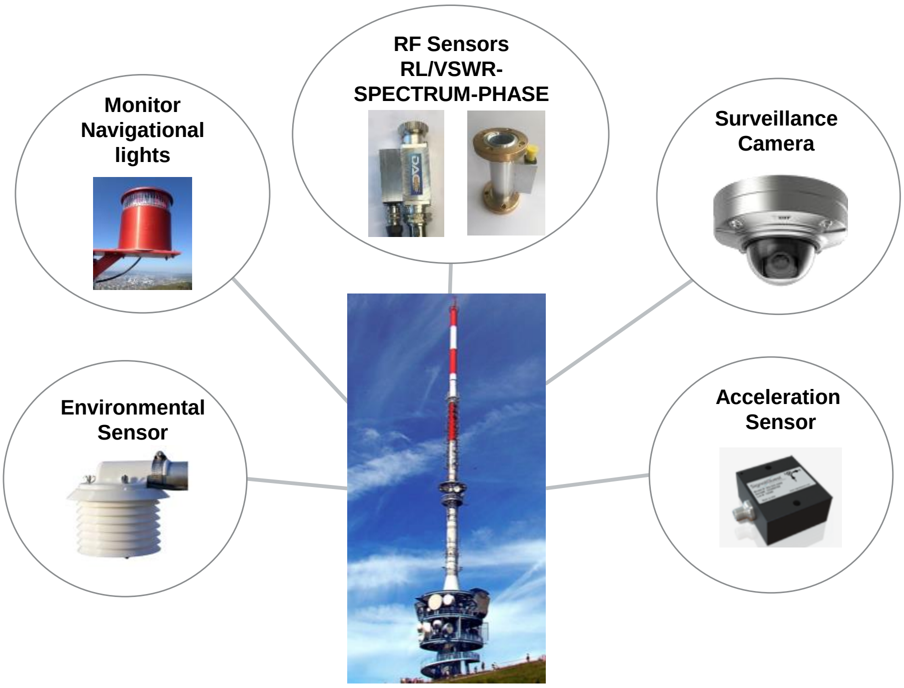


Figure 4: IoT for a broadcast tower

Are this data beneficial for the operator?

Data collection cannot only help to streamline operation and maintenance, it also safes costs and increases the quality of the service. This valuable data can be analysed and used to control the equipment in a dynamic manner. This will allow to:

- Increase the quality of the service with dynamic power adaptation
- Qualify installations, learn about overall system behavior

- Qualify suppliers, learn about equipment/system behavior over time and environmental changes
- Increase the safety of new constructions
- Lower power consumption by adjusting amplifier control to radiation condition (humidity, temperature, ice)

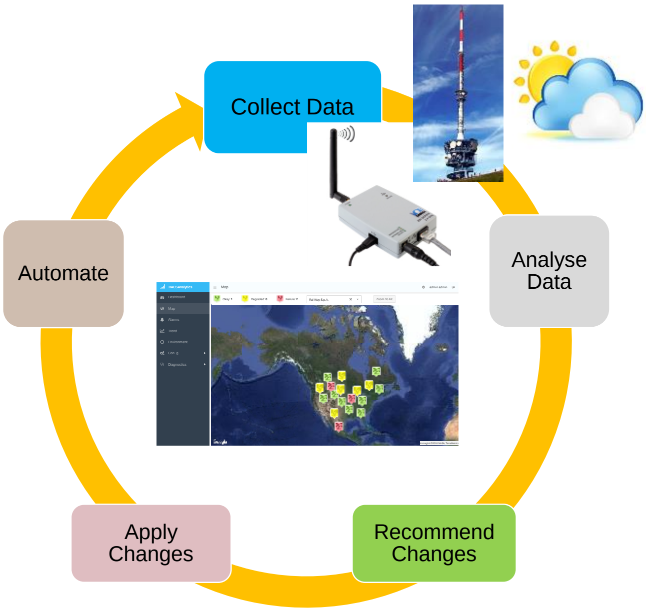


Figure 5: Adaptive dynamic system control

Managing actively the rf-power of the station based on rf-performance data could help to safe over time a lot of energy. Normally power calculation and system lay-out is done for worst case situation, e.g. snow and ice conditions. In good radiation conditions the rf-power could be lowered without reducing the quality of the service, this is another great advantage deploying an IoT system in this environment.

8 Conclusion

The operators of rf-systems face various challenges through competing technologies, cost pressure and very high service quality expectations. Industry conversion and structural changes facilitate co-location of rf-system and the need of transparency for shared infrastructure (root cause).
Preventive maintenance is currently based on tower/site inspection by people, there is no on-line, real time system in place supporting these possibilities. Up to 50% of system breakdowns and sudden failures could be prevented with a suited IoT application (monitoring system), increasing as well the safety of the installations.
Investigation show that Return on Investment (RoI) of such an IoT system is positive, if the operator take full advantage of the technology and cost factors are managed accordingly. These obvious benefits for the operator are further increased taking full advantage of the recorded data for optimizing the operation and dynamically managing the rf-power.

The IoT System evaluated should address these critical needs and possibly to be deployed in retrofit situations and new installations (including enhancements or partial replacements). IoT solutions/Monitoring systems are new for the industry but will be over time be a standard component of rf-system installations with great benefits for the operators, content providers and service users.

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DAC System SA

DAC System is a supplier of innovative and unique IoT/monitoring systems. The self-developed products are based on patented technologies and are manufactured in Switzerland acc. to the highest quality standards.

DAC System continuously improves and enhances functions and features of its products.

The products and total system solutions are delivered world wide to broadcast and LMR network operators.

The development engineers are able to customize products and solutions for our customers in a very short time.

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