

A Multivocal Literature Survey of Patterns for Serverless work (work-as-a-Service)

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Abstract. Serverless can be defined as one of the new technologies which allows businesses to decrease the overhead of scaling, managing and provisioning organization in general. Serverless is becoming more popular as businesses migrate current applications to such novel paradigm. Patterns for managing and composing the functions of serverless were suggested by various practitioners. Yet, a few of such patterns provide multiple solutions to the same problem, making it difficult to choose the best solution for each one of the problems. The objective of this work is to classify the patterns and report potential issues and benefits, so that practitioners can better understand them. This study used a Multi-vocal Literature Review (MLR) approach, scouring peer-reviewed as well as grey literature for patterns (common solutions to common problems), as well as issues and benefits. This work identified 32 patterns among 24 works, categorizing them as aggregation, orchestration, availability, event management, authorization and communication. Even in the case where a small number of the patterns suggested distinctive solutions to comparable issues, practitioners have suggested a set of the rather consistent patterns. A few patterns arose in response to the limitations of serverless, whereas others arose in response to more traditional technical issues (for example, publisher/subscriber).

Keywords. function as a service, serverless, cloud, serverless functions

1 Introduction

Serverless computing can be considered as one of the novel paradigms which enables businesses to deploy and develop deploy applications easily and quickly without handling any underlying infrastructure (Lloyd et al., 2018). AWS Lambda, Azure and Google Cloud Functions are some of the serverless computing platforms that were suggested in the market. Those platforms allow developers to concentrate solely on business logic, leaving the infrastructure provisioning, monitoring management and scaling to the cloud service providers [S1]. FaaS (which has also been known as "serverless functions") is the most well-known implementation regarding serverless computing. Developers must only use the short-running functions' source code as well as defining triggers to e executing them when using FaaS. On-demand, the FaaS provider bills and executes the functions as isolated instances, scaling their execution. In the rest of this paper, FaaS will be referred to as "Serverless Functions." A very significant problem with server-less functions is non-existence of patterns for combining various to develop a partial or complete application. Previous work (Leitner et al., 2019) [S1] has also highlighted the non-existence of patterns in serverless functions, while practitioners are frequently addressing such issue in technical talks, frequently suggesting patterns that are

incompatible. As a result, for assisting researchers and practitioners in mapping the present advanced serverless patterns, this study indicates a classification and review of patterns suggested via researchers and practitioners. This study utilized a MLR (Garoussi *et al.*, 2019) for capturing a state of practice and state of the art in the area, such as grey and white literature (industrial whitepapers, blog posts, practitioner talks and books). The study chose 24 studies that were published between 2017 and the end of Jan. 2019. After that, the architectural patterns' taxonomy has been proposed, which was aimed to solve a group of common issues, as well as their advantages and disadvantages. This work makes two contributions, which are primarily aimed at researchers and practitioners:

- Practitioners might use 32 serverless patterns, divided into 5 categories, in the study.
- Identifying issues and trends that are related to serverless patterns.
- The drawbacks and advantages of patterns as it has been described in literature and via practitioners.

The rest of study is organized as follows. The study is compared to other literature reviews, also the related works are presented in Section 2. The research methodology is presented in Section 3, while the findings are provided in Section 4. The threats to validity and the results are discussed in Section 5. Section 6 comes to a conclusion.

2 Related Work

Regardless of the fact that serverless technology was only recently introduced, there is a lot of research going on in such area. Between 2017 and 2019, approximately 200 papers were published, according to the Serverless Literature Dataset-1 (Spillner and Al-Ameen, 2018). The literature reviews in this field are presented in this section, as well as related works which looked into server-less patterns.

2.1 Serverless Literature Review: The literature on Serverless has been observed by 5 works.

- (Lynn *et al.*, 2017), have evaluated the characteristics that are related to 7 server-less platforms of computing recognizing their issues and benefits.
- (Alqaryouti *et al.*, 2018) have carried out a complete literature review that classifies the variety of the proposals that have been associated with the tasks of scheduling in the clouds. They have characterized the approaches for the minimization of the time of execution. Differently from the present study, they have highlighted the problems in the scheduling, however, not investigated patterns.
- (Werner & Kuhlenkamp, 2018), have carried out a systematic review for the purpose of mapping the empirical evidences on serverless functions. They carried out 26 experiments on 5 qualities, including scalability, performance and availability. In such regard, their objective wasn't targeted to the architectural pattern's identification.
- (Sadaqat *et al.*, 2018) suggested a nonpeer reviewed MLR for identifying the core technological components related to serverless computing, challenges and benefits, while they didn't concentrate upon the patterns.
- Leitner *et al.* [S10], have conducted a mixed method research that add more importance to such new field through identifying peer-reviewed as well as grey literature on server-less patterns. The major aim has been to recognize the form of applications which majorly take advantage from serverless technology, also the patterns which were utilized for implementing them. Thus, there are five patterns recognized in the case when conducting serverless based services. The research discussed the limitations with regard to configuration, development overhead and performance which is caused by each one of the patterns. In contrast to the presented study, they elicited the patterns from a survey, whereas this study aims to understand the patterns indicated in literature. Whereas an empirical evaluation regarding the patterns

might be of high importance, this study also aims to classify patterns suggested via practitioner's talks, which could highly affect other practitioners in using patterns that will be used by them in their applications.

2.2 Server-less Patterns There are 6 peer reviewed studies already studied the serverless patterns, whereas a single study examined the antipatterns (Taibi & Nupponen, 2020). In [S 7], the researchers concentrated on serverless-based patterns of the design for enhancing cloud-based services security. Also, they have provided 6 design patterns which might be combined for building a threat intelligent services, like virus scanning and intrusion detection. Rabah *et al.* [S 24], reported a patent in which they have suggested patterns to handle composing serverless functions and building new applications. Bernstein et al. [S6], reported an instance of potential pattern which might be developed based on serverless services. The major aim is processing event-streams by means of single threaded virtual actors, which causes an increase in parallel execution and performance of tasks. Gadepali *et al.* [S15], reported an architectural pattern which deals with possible applications that are related to serverless technology along with Edge Computing (Pahl *et al.*, 2019). Taibi and Nupponen, 2020, reported industrial survey in which they have distilled a group of the anti patterns from major issues that are encountered by practitioners, whereas creating serverless based applications. With regard to nonpeer reviewed literature, a book that has been published lately [S 8], presents a more thorough explanation regarding server-less computing as well as various design patterns for considering when to architect an application. In particular, the book indicates 4 main pattern classes, which are patterns of the extract transformation load (ETL), web application patterns, deployment and patterns of the automation, also big data patterns. In [S13], the researcher provides strategies for helping the companies in embracing serverless technology through exhibiting concrete use cases, patterns and architectural designs. In addition, the book reports 5 patterns and the way for implementing them. It is noted that the 5 patterns aren't unique to serverless technology, yet, implementing them with the use of serverless services and components might be beneficial. The presented study is different from current literature not just via concentrating on patterns from certain domain (security) or solving specific problem (streaming data), yet, this work used a systematic method to identify all current patterns such as non-peer reviewed and peer-reviewed studies.

3 Design of the Study There are architectural patterns for a variety of architectural styles. In addition, there have been patterns regarding service oriented architectures (Erl, 2008), patterns related to object oriented monolithic systems (Gamma *et al.*, 1994) patterns for micro-services (Taibi *et al.*, 2018) (Taibi *et al.*, 2019 a), along with patterns for a variety of other architectural styles (Taibi et al., 2019b). Patterns in serverless functions have only recently been discussed by practitioners. This study conducts a MLR for eliciting the current serverless functions patterns (Garousi et al., 2019). Also, this work concentrates on answering the next questions in particular:

RQ-1 What are the various architectural patterns that have been based on serverless? RQ2 What are the cons and pros of such patterns?

The 1st question concerns the definition of Server-less technologies, as well as the way that the practitioners and researchers can specify particular patterns for developing Server-less based services. RQ 2 examines the advantages and the disadvantages regarding every one of patterns, which take into account 2 major perspectives: practitioners who have put it to use in real settings and researchers who were experimenting with the new technology.

. 3.1 Multi-vocal Literature Review MLR is one of the literature review types which involves not just peer-reviewed and academic literature, yet also practitioner opinions and literature

created by industry professionals. MLR can be defined as a two-edged sword in that it doesn't solely depend on peer-reviewed studies, unlike the traditional Systematic Literature Review (SLR). From practical and industrial perspectives, this might be extremely beneficial in answering questions. Considering unfounded viewpoints and claims, yet, might result in skewed conclusions. Gray literature (GL) is used by MLR, and it can take various forms, such as government, industrial and organizational reports, also publicly-available resources like online articles and blogs. When new fields are under-development, one might identify more GL on a topic than the peer reviewed, because academic researches depend on more systematic process which takes longer (journal or conference submission, publication and notifications). Only a few researches have addressed the topic of server-less patterns in our context, due to the fact that serverless technology remains fairly new. As a result, incorporating GL into our research allows combining academic studies with GL's current state of practice. This work uses the MLR protocol suggested via Garousi et al. for reducing the bias in the sectioning process (Garoussi *et al.*, 2019).

3.2 The Process of the Search: There are 3 major steps for the MLR protocol: defining the search process, selection of the source and evaluation of the literature, as shown in Figure 1. According to the RQ's in this work, the next search string has been created ("pattern" OR "best practice" OR "architecture" OR "issue" OR "smell" OR "problem" OR "compos*" OR "anti-pattern" OR "anti-pattern") AND ("server-less" OR "function as a service" OR "IaaS" OR "function-as-a-service" OR "Function" OR "Lambda"). In addition, the search string has been utilized in digital libraries and in google search engine. The latter was applied for tracking grey literature, whereas the former targets peer reviewed studies. In this work, the considered digital libraries are SpringerLink, IEEEExplore, ACM, Google Scholar, Scopus and Science Direct. A total of 127 results were yielded by the search process. **Due to Figure 1: MLR search process**

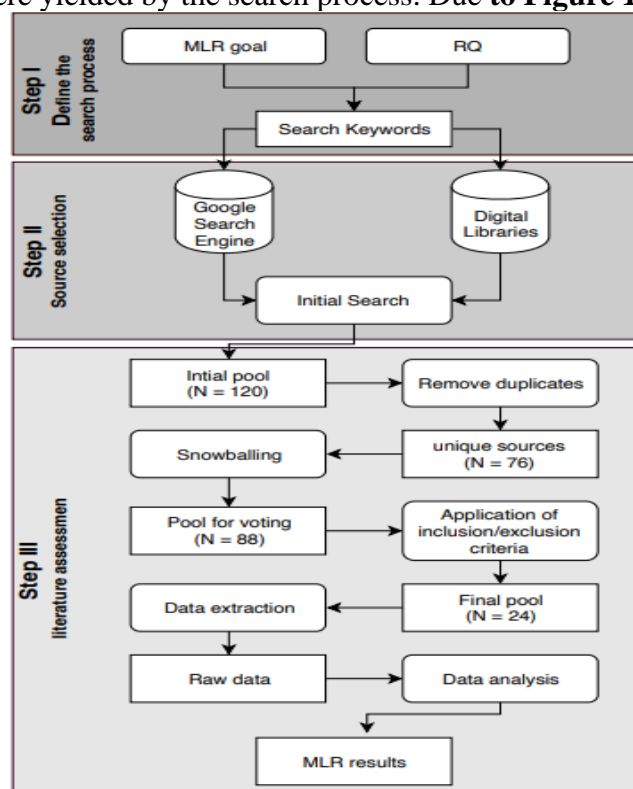


Figure 1: MLR search process

The results are limited to the first 10 pages. Then, the results are filtered for removing duplicates. The process led to 76 distinctive sources, 7 peer reviewed studies, 65 practitioners' blogs, one patent, 2 videos and one Power-Point presentation. This work involved 12 more blogs after applying the snow-balling process to the links and references in the initial set of results, for a total of 88 sources. This work generated a set of exclusion and inclusion criteria to help us choose the best sources for our research. The authors independently applied the criteria to full content of 10GLs that have been chosen randomly from result pool for the purpose of testing their applicability. The criteria were re-formulated to be more accurate in light of a few discussions and disagreements of the inclusion regarding 3 GLs. This work provided the capability for capturing the majority of sources representing the advancements in serverless patterns with the use of such exclusion and inclusion criteria. Table 1 shows the final list related to exclusion and inclusion criteria. The sources were independently evaluated via each one of the authors, who indicated whether each source meet or doesn't meet criteria. In the event of a disagreement, all of authors have been involved in resolving any questions regarding the sources that are in question.

Table1: criterions of inclusion and exclusion. (All criteria below have to be satisfied by the sources that have been chosen)

Inclusion Criteria
GLs on serverless functions describing at least one pattern
Exclusion Criteria
GLs NOT in English
GLs using the term 'FaaS' or "serverless" for other purposes (e.g. in the food service industry)
GLs mentioning a pattern but not describing it
Duplicated GLs
GLs only summarizing other GLs
GLs selling a third party product
GLs reporting only anti-patterns, as they are out of scope of this work

Table2: extraction of the MLR Form

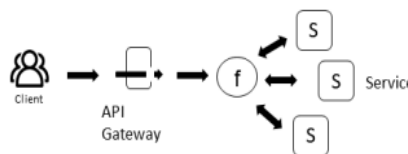
Attribute	Description
Source	The publication source
Publication date	when the source was published
Authors	The author or list of authors
Title	The source title
Pattern Name	The given name of the pattern
Pattern Description	A description of the pattern
Problem it solves	The specific problem the pattern solves
Advantages	Advantages of implementing this pattern
Limitations	Limitations (e.g. platform dependent)

Ultimately, this study used criteria that have been suggested via Garousi et al. to conduct quality assessment (Garousi et al., 2019). Also, were obtained a total of 24 distinctive sources from which patterns have been extracted after all of the sources passed the quality criteria. Table 2 defines the extraction form that was used for extracting the attributes of interest. We categorized the patterns on the basis of problems they were designed to solve using extracted data. If the

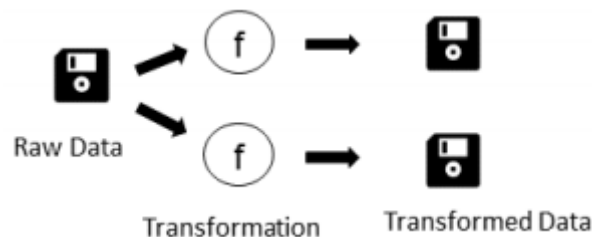
selected sources used various names for same pattern, the most frequent name is chosen, whereas if there were an equal number of sources indicating same pattern, yet using various names, we debated and name that has been chosen as the most understandable.

4 Patterns that have been Suggested by the Practitioners We reported 32 patterns from the chosen GLs and categorized them into 5 categories: aggregation and orchestration, event management, availability, communication, and authorization. TRQs are answered for each pattern separately to make reading easier, particularly from practitioners' perspective. Initially, this work indicates the problem that each one of the patterns is meant to solve (RQ1), followed by issues and benefits, as indicated via GLs (RQ2). Table 3 lists all of the patterns, as well as the alternate names used in GL's.

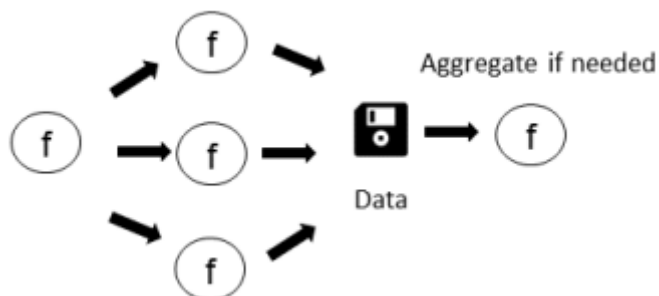
4.1 Aggregation and Orchestration: Those patterns might be utilized for composing serverless functions or orchestrating their executions in order to create more complicated icroservices or functions. Aggregator [S 12] [S 2] [S 1] (which has also been referred to as "Durable functions" [S 3]) : Problem: the exposure of one end-point for many API. Solutions: A function separately calls API, after that aggregating results as well as exposing them as singular end-point



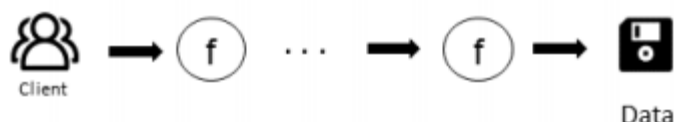
Data Lake [S 4] [S 5]: Problem: Keep up with the emerging needs regarding data processing and transformation might be complicated. Solutions: The data lake can be defined as a physical storage related to raw data in which the data is processed as well as deleted least possible. Organizing it with the sensible meta-data naming as times is essential to keep order. Benefit: data is often the same independently from moment's requirements. It might be transformed just in time as needed



Fan-In/Fan-Out [S 12] [S 8] (Mc Grath *et al.*, 2016) [S 2] [S 4] (which has also been referred to as "Virtual Actors" [S 6], "Data transformation" [S 7], "Processor" [S 9], "Fire triggers and transformations" [S 3]): Problems: Enabling long tasks execution exceeding the maximal time of execution (which is comparable to Function Chain). Solutions: Splitting the work parallel tasks as well as aggregating the results in end. Also, the parallel execution results in fast completion. Problems: the strong coupling amongst the chained functions. With regard to function chain, tasks that are split between functions might be complicated [S10]



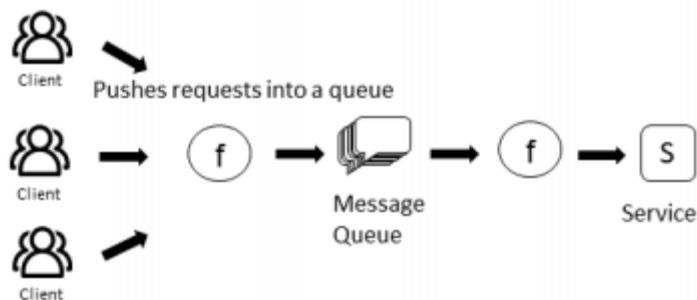
Function chain [S 10] [S 3]: Problems: Allow executing long tasks, exceeding the maximal time of the execution (longer than 15mins in Lambda). Solutions: Combining the functions in the chain. In addition, an initial function initiates computations, whereas keeping track regarding the remainder of the execution time. Also, prior to reaching maximal time of execution, the function is invoking a different function in an asynchronous manner, pass every one of the parameters that are required for continuing the computations. In addition, the initial function might after that be terminated without impacting the next function in a chain. Issue: Strong coupling amongst chained functions, an increase in the number of the functions. Splitting tasks between functions might be complicated [S 10]



Proxy [S 11] (which has also been referred to as the “Command pattern” [S 13], “Anti-Corruption Layer” [S3]): Problems: Function’s integration with a legacy system. Solution: Creating a function which is acting as proxy for another service, handle any required protocol or data format translation. Benefits: Easy-to-access and clean APIs for the client.

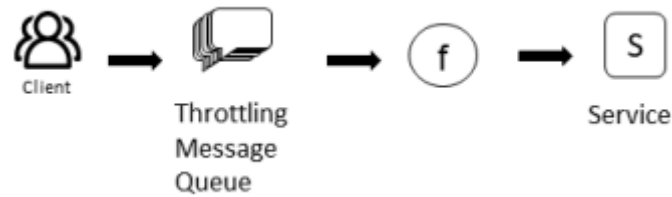


Queue-Based Load Leveling [S 8] [S 2] [S 3] (which has also been referred to as “Scalable Web-hook” [S 12], “The Throttler” [S 1]): Problem Building scalable webhooks with nonscalable backends. Webhooks enable to alter or augment the web page or web applications behavior, with custom call-backs. Solutions: Comparable to frugal consumer, queue service for triggering a function might be utilized, ant that permits the queueing of the requests under the heavy loads



Frugal Consumers [S 12]: Problems: Increasing the non-scalable back-ends’ scalability. Solutions: A function which operates by processing the requests regarding multiple services

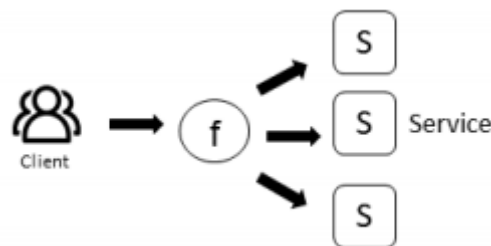
(or functions) directly posting messages to a message queue



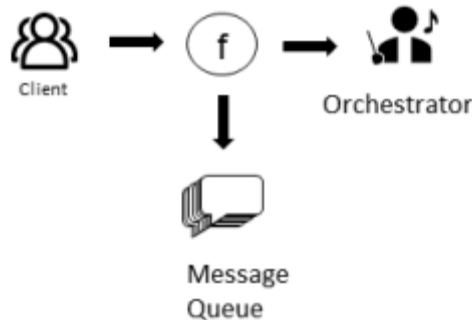
Internal APIs [S 12]: Problems: Access to micro-services which have just been accessed within cloud infrastructure. Solutions: Leaving the API Gate-way, also, directly calling functions HTTP with the use of the Type of the Invocation. Benefit: Increased security as services aren't accessible from outside.

Robust APIs [S 2] [S 12] (which has also been referred to as "The Gateway" [S3]): Problems: Clients usually identify services in backend that they wish to utilize. Solution: Using API Gateway for granting access for clients to the chosen services. Benefit: Allow handling more individually clients. Issue: Increasing complexity.

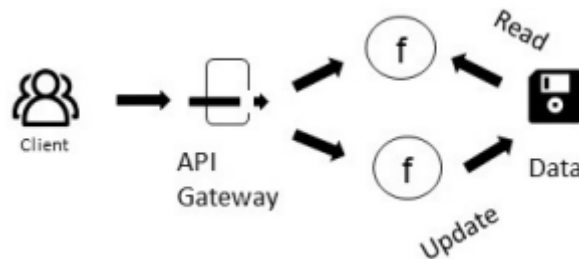
Router [S 12] (also referred to as "Routing Function" [S 13], "Decoupled Messaging" [S 2], "Data probing" [S 9]): Problems: Distributing execution on the basis of pay-load, without paying extra costs of systems of the orchestration that are used in state machine patterns. Solutions: Creating a function acting as a router, receives requests as well as invoke the associated functions according to payload. Benefits: Easy implementations. Problems: the function of the routing must be handled. Also, it might provide performance bottleneck and be a single failure point. Double billing, due to the fact that the routing function must wait till execution is terminated via the target function



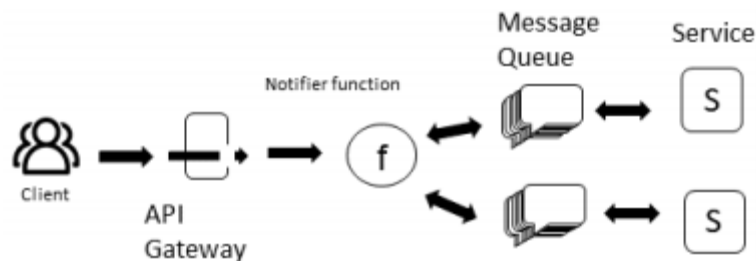
Thick Clients [S 13]: Problems: Any of the intermediary layers between client and service results in increasing the latency and costs. Solutions: Allowing the clients for directly accessing the services and orchestrating the workflows. Advantages: Increased performance, increased separation of concerns, and reduced costs at the server-side, (Roberts, 2016). State Machine [S 7] [S 2][S 12]: Problems: Orchestrating and coordinating the functions. Solution: Adopting server-less orchestration system like the AWS Step Functions², Azure Durable Functions³, or IBM Composer⁴ for the orchestration of the complicated tasks. Issues: The system complexity is increased, in addition to the development efforts



4.2 Event-Management The communication problems are solved by these patterns. Segregation of Responsibility [S 3]: Problems: In the case when the same functions applied for data updates and queries, it will cause an increase in the risks of becoming inflexible. Solution: Segregate functions which are updating and reading from data sources. Use "Queries and Commands" for adequate function for avoiding such congestion

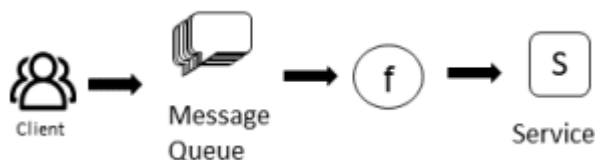


Distributed Triggers [S 12] (which have also been referred to as "Event Broadcast" [S13]): Problems: Coupling a topic of the message queue only with its own services. Solutions: Coupling several multiple services in one function of notification, which is possible through the message queues. Such setup can be considered efficient in the case where topics have only one purpose and require no data outside its microservice. Problems: The subscription to queue topic is still the responsibility of individual services

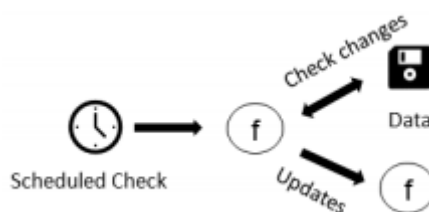


. **FIFO** [S 12][S 13]: Problems: Creating FIFO Queue for the server-less functions. Numerous messages don't work with the FIFO method (1st in, 1st out). Solutions: Using a cronjob like the AWS Cloud-watch periodically invoking function in an asynchronous manner. Then, function's concurrency is set to 1 so that there aren't any attempts at running competing requests in parallel. The function would poll the queue for (up to 10) ordered messages and performs any processing that it requires. As soon as the processing has been complete, function will remove messages from queue and after that invoke itself once more (in an asynchronous manner). Such process will be repeated until all items were removed from queue. Benefit: Simple sequentialization. Issue: Cascading effects [S 12]: in the case where function has been busy in the processing of the other messages, cronjob will fail due to the setting of the concurrency. In the case of the blocking of the self-invocation, the re-try will continue cascading.

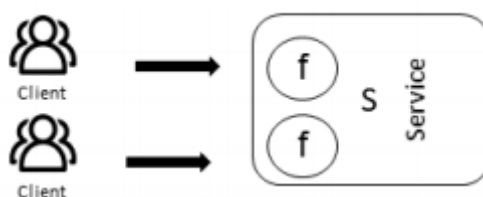
Internal Handoff [S12]: Problems: Using the invocation Type (Event) for the asynchronous events. Solutions: Function would stop automatically in the case where execution has been finished and re-tries automatically whenever it needs to. Utilizing a message queue for attaching a Dead Letter Queue enables at capturing the failures



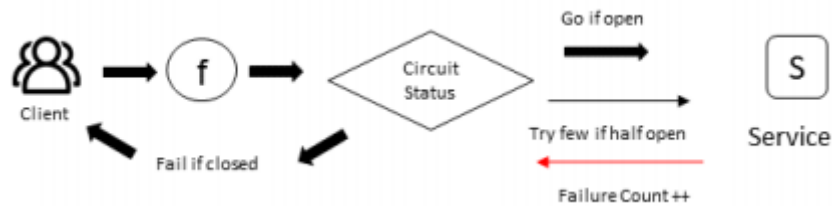
Periodic Invoker [S 7]: Problems: Executing the tasks in a periodic manner. Solutions: Subscribing function to a scheduler, like the Google Cloud Scheduler, AWS Cloud Watch, or Azure Scheduler. Advantages: Running the functions in a periodic manner with no need for keeping them alive permanently. **Processor of Polling Events** [S 11] (which has also been referred to as “Polling consumer” [S 22]): Problems: Reacting to the external systems’ states changes which don’t publish the events Solutions: Using Periodic Invoker pattern for checking the service state. Benefit: Running the functions in a periodic manner with no need for keeping a function alive permanently as the listener



4.3 Patterns of Availability: This set of the patterns is helpful in solving the issues that are related to the availability, leading to the reduction of the time of warm-up, and potential failures. **Bulkhead** [S20], [S3]: issue: in the case where crucial, possibly heavy-load function has failed, the entire system risks will be compromised. Solution: to partition the work-loads to separate pools. Which may be created according to the consumers’ availability or load. Advantages: isolating the failure and reducing risks of failure chain reaction



Circuit breaker [S 12] [S 14]: Issue: tracks the slow or failed calls of the API. Solution: in the case where the amount of the failures reaches a specific threshold, “open” the circuit will immediately send the errors back to calling client without even an attempt at calling API. Following a brief time-out, system “half open” circuit, transmitting just a small number of the requests through for seeing whether an API finally responds accurately. The rest of the requests get an error. In the case where the sample requests have been successful, the system “close” circuit and begin to let the traffic through. On the other hand, in the case where some or all of these requests fail, the circuit will be open again. Advantages: Cost savings for the synchronous requests

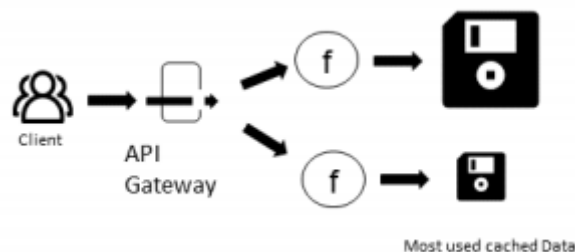


Compiled Functions [S 15]: issue: Server-less cloud computing would be considered as an optimal fit for the IoT, in particular, at the Edge where it wouldn't be so heavy-weight in the foot-print of the memory and the time of invocation. Solution: A high-level specialized innovative compiled Server-less language may lead to the reduction of time of invocation and memory footprint. Which might result in creating the viability of the Edge technology in a cloud.

Function warmer [S 12] [S 16] [S 23] (that has also been referred to as the “Warmer service” [S9], ”Function Pinging” [S 10], “Keeping Functions Warm” [S 8], “Cold Start” [S 21], “keep-alive” [S 3]): issue: the decrease of the cold start time, delay between a function execution post somebody invoking it. The execution of the Server-less functions is carried out in the containers, encapsulating and executing them. In the case where they're invoked, container keeps to run only for a specific period of time following the function execution (warm) and in the case where a different request arrives prior to the shutdown, the request will be immediately served. Cold start can take from 1sec to 3sec [S 2] [S 23]. For instance, Azure (Shilkov., 19a) and AWS (Shilkov, 19b) recycle the idle instances of the function following a fixed 20min and 10min periods respectively. Solution: periodically Pinging the function for the purpose of keeping it warm. Benefits: Reducing the response time from 3sec to 200ms. Issue: Increase of the cost, even in the case of being limited to only 1 call each 10min-15min.

Oversize Function [S 10]: Problems: In the Server-less there is no possibility for choosing the CPU that it will run on. Solutions: requesting bigger grants of the memory, as well as a faster VM, even in the case where there is no need for additional memory.

Read-heavy report engines [S12][S2]: Problems: Overcoming down-stream limits of read-intensive applications. Solutions: Using data caches and creating specialized data views that are most often queried. Benefit, enhanced performance



. Eventually Consistent [S 12]: Issue,,: data is replicated between the services for the purpose of keeping them consistent. Solutions: Using the data-base streaming services (for example, Dynamo DB stream) for the triggering of the events that have been made on data-base from the earlier functions and using data once more for whatever required



Time-out [S 17]: Problems: time-out for the API Gateway is 29sec. Which can be considered as a long time for the user and creates bad experiences with service. Solutions: Reduction of time-out to a shorter span, preferred about 3sec-6sec.

Discussions:

This work results are highlighting the fact that the server-less pattern remains unclear. Various practitioners proposed similar and usually discordant patterns, for the purpose of solving such issues. Some of the patterns have been only stated by one of the sources, whereas the others have been stated by different sources, which confirm the significance that has been given by practitioners. Whereas the continuous server-less platform evolution, like introducing new tools, may be advantageous for the practitioners, it can possibly confuse the practitioners in understanding which one of the solutions is more advantageous to be adopted. For instance, the AWS lambda adapted the queue service (SQS) for the purpose of enabling the FIFO messages, which is why, it isn't required anymore managing the re-driving policies (Frugal Consumer patterns). On the other hand, yet, the FIFO messages remain important to be managed manually in the Azure. Different tools were proposed in the past years, and will possibly keep being presented in future, which results in the increase of the complexity of the decision in the case of deciding the pattern that needs to be adopted. It has been interesting noticing that numerous patterns were created for the purpose of working around the server-less obstacles. For instance, function warmer was created for the purpose of circumventing long start-up issue of the functions. Other patterns have been inherited from other monolithic systems and cloud-domains. For instance, gate-keeper and valet key have been utilized as well in the micro-services. Because of this work, the practitioners will be capable of accessing description of all the patterns in a single report, in combination with the analyses of perceived advantages of every one of the patterns, and potential issues, which may emerge when utilizing them. The researchers are capable of additionally validating patterns, taking under consideration their usefulness or extending them.

xperienced reports and experiential researches.

. 6 Conclusions

As the number of the companies developing and utilizing the server-less applications keeps rising, the natural question is that everybody who joins this direction asks about are optimal practices or design patterns that are to be followed for the purpose of making the best of that innovative technology. Up until now, the majority of the companies were researching new territories through the application of the known patterns and approaches that come from the well-established methodologies (for example, the micro-services and web services). On the other hand, with the server-less technologies becoming widely utilized, 2 pattern classes begin emerging. The first one of the classes represents the available patterns, which were adapted from the available technologies for the purpose of fitting the server-less concepts, others were rather specifically developed for the addressing of the needs of the server-less implementations. The practitioners have suggested various patterns, and community has already been aware of a number of them. The community may be observed in the early stage of the adoption. None-the-less, the available reports have highlighted the value of those patterns, even though the

complexities that have been introduced by the server-less are only slowly emerging. None-the-less, pattern catalog, which has been obtained from literature and was confirmed by survey provides an important base for the researchers as well as the practitioners. In such context of the fast-evolving technology, more tools are going to be developed, which may be requiring either new patterns or turning the ones that are work-around for the limitations obsolete. Here, there is a necessity for the continuous updates of any pattern catalog. The future works include validating the precise usefulness of those patterns in the contexts of more concrete application and identification of the anti-patterns.

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