OpenWhisk Package Specification

Version 0.8, Working Draft 09

Notational Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119.

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Introduction

OpenWhisk™ is an open source, distributed Serverless computing project.

Specifically, it is able to execute application logic (*Actions*) in response to events (*Triggers*) from external sources (*Feeds*) governed by simple conditional logic (*Rules*) around the event data.

It provides a programming model for registering and managing *Actions*, *Triggers* and *Rules* supported by a REST-based Command Line Interface (CLI) along with tooling to support packaging and catalog services.

The project includes a catalog of built-in system and utility *Actions* and *Feeds*, along with a robust set of samples that demonstrate how to integrate OpenWhisk with various external service providers (e.g., GitHub, Slack, etc.) along with several platform and run-time Software Development Kits (SDKs).

The code for the Actions, along with any support services implementing *Feeds*, are packaged according to this specification to be compatible with the OpenWhisk catalog and its tooling. It also serves as a means for architects and developers to model OpenWhisk package Actions as part of full, event-driven services and applications providing the necessary information for artifact and data type validation along with package management operations.

Compatibility

This specification is intended to be compatible with the following specifications:

- *OpenWhisk API which is defined as an OpenAPI document:*
    - https://raw.githubusercontent.com/openwhisk/openwhisk/master/core/controller/src/main/resources/whiskswagger.json
- *OpenAPI Specification when defining REST APIs and parameters:*
    - https://github.com/OAI/OpenAPI-Specification/blob/master/versions/2.0.md

34   Revision History

Version	Date	Notes
0.8.1	2016-11-03	Initial public point draft, Working Draft 01
0.8.2	2016-12-12	Working Draft 02, Add. Use cases, examples
0.8.3	2017-02-02	Working Draft 03, Add use cases, examples, $ notation
0.8.4	2017-04-18	Working Draft 04, Support JSON parameter type; Clarify use of Parameter single-line grammar and inferred types. Add support for API Gateway mappings. Add support for Web Actions
0.8.5	2017-04-21	Add support for "dependencies", that is allow automatic deployment of other OpenWhisk packages (from GitHub) that the current package declares as a dependency.
0.8.6	2017-07-25	• Clarified requirements for $ dollar notation. • Updated conceptual Manifest/Deployment File processing images.
0.8.7	2017-08-24	• Added explicit Application entity and grammar. • Added API listing to Package entity. • Cleaned up pseudo-grammar which contained various uses of credentials in places not intended. • Fixed Polygon Tracking example (indentation incorrect).
0.8.8	2017-08-29	• Created a simplified API entity (i.e., "api") grammar that allows multiple sets of named APIs for the same basepath. • Acknowledge PHP as supported runtime (kind). • Added "sequences" entity as a convenient way to declare action sequences in the manifest. Updated supported runtime values.
0.8.9	2017-09-22	• Clarified "version" key requirements for Package (required) and Action (optional); removed from shared entity schema. • Made "license" key optional for package. • keyword "package" (singular) and "packages" (plural) both allowed. • Adjusted use case examples to reflect these changes. • Rework of schema use cases into full, ste-by-step examples.

35

Table of Contents

Programming Model

OpenWhisk Entities

OpenWhiske uses the following entities to describe its programming model:

Action

A stateless, relatively short-running function (*on the order of seconds or even milliseconds*) invoked as an event handler.

Trigger

The name for a class of events. Triggers represent the events (and their data) themselves without any concept of how they were generated.

Rule

A mapping from a Trigger to an Action which may contain simple conditional logic. OpenWhisk evaluates incoming events (that belong to a Trigger) and invokes the assigned Action (event handler).

Event Source

An Event Source is the descriptor (edge) for an Event Producer (or provider). It describes the Event Format(s) produced, as well as any configuration and subscription capablities.

Feed

A Feed is an optional service that represents and controls the stream which all belong to a Trigger. A feed provides operations called **feed actions** which handle creating, deleting, pausing, and resuming the stream of events. The feed action typically interacts with external services which produce the events

Package

A named, shared collection of Actions and Feeds. The goal of this specification is to describe OpenWhisk packages and their component entities and resources to enable an open-ecosystem.

Packages are designed to be first-class entities within the OpenWhisk platform to be used by tooling such as catalogs (repositories), associated package managers, installers, etc.

Note: Not all actions must belong to packages, but can exist under a namespace.

Cardinality

Trigger to Action

With the appropriate set of Rules, it's possible for a single Trigger (event) to invoke multiple Actions, or for an Action to be invoked as a response to events from multiple Triggers.

125 ## Conceptual representation

126
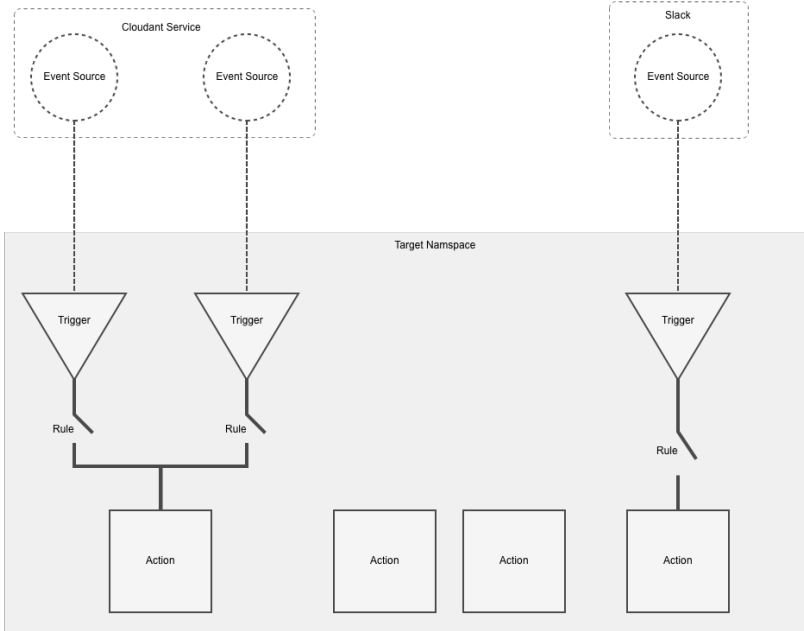
127 # Package processing

128 This document defines two file artifacts that are used to deploy Packages to a target OpenWhisk platform;
129 these include:

130 - **Package Manifest file**: Contains the Package definition along with any included Action, Trigger or
131 Rule definitions that comprise the package. This file includes the schema of input and output data to
132 each entity for validation purposes.
133 - **Deployment file**: Contains the values and bindings used configure a Package to a target OpenWhisk
134 platform provider's environment and supply input parameter values for Packages, Actions and
135 Triggers. This can include Namespace bindings, security and policy information.

136 ## Conceptual Package creation and publishing

137 The following diagram illustates how a developer would create OpenWhisk code artifacts and
138 associate a Package Manifest file that describes them for deployment and reuse.

1. Developer **creates** and **reposits** Serverless code, including:
   - Actions (functions) and
   - Feeds for Event Sources (i.e., Event Providers)

2. Creates a **Package Manifest File** which describes the Serverless service's:
   - Repositories (source code locations)
   - Parameter schema (for Actions and Feeds)
   - Configuration and Lifecycle APIs for Feeds
   - Event Sources (and corresponding Event schema)
   - Triggers and Rules
   - Compositions of Actions
   - Annotations (tags, User Interface hints, etc.)

3. Publishes **Package Manifests** to enable Catalog features for Serverless services:
   - Automated or manual Discovery and Search
   - Graphical Display / Selection
   - Functional applicability
   - Compositional type validation

Serverless Developer

Repositories

Package Manifest File

Catalogs (Object Storage)

139

Conceptual tooling integration and deployment

141 The following diagram illustrates how Package manifests can be leveraged by developer tooling to
142 integrate OpenWhisk Serverless functions.

1. Developer **searches** and **discovers** OpenWhisk packages described by the **Package Manifest** in one or more Catalogs, that can:
   - Help analyze, augment and annotate application information and data.
   - Add value added functionality to a base application or workflow.

2. Imports Open **Package Manifest Files** and related code and artifacts into development tooling, including:
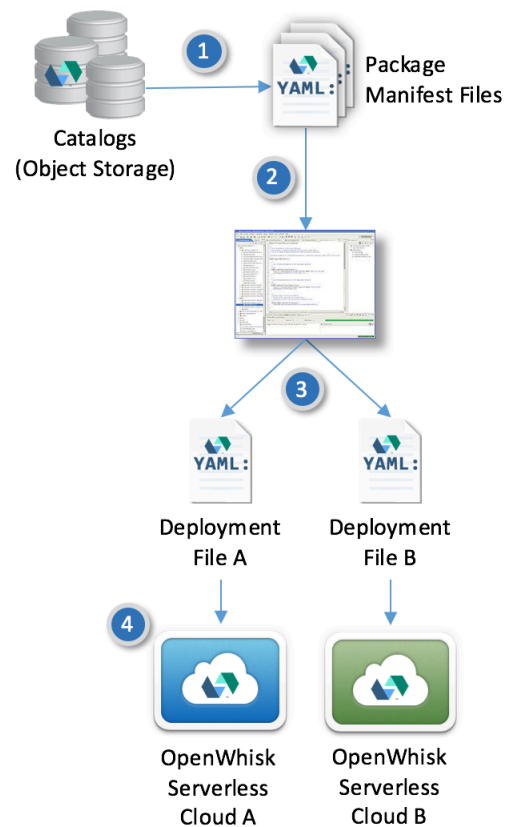   - Project and Application (source code) Repositories
   - Integrated Development Environments (IDEs)
   - Cloud-based design, workflow and application workspaces.

3. Creates OpenWhisk **Deployment Files** for one or more target OpenWhisk enabled Clouds, with
   - Parameter values for desired target environment
   - Appropriate Credentials and configurations for chosen Event Sources and Feeds.

4. Deploys **Packages** (i.e., Actions, Triggers, Feeds, etc.) to OpenWhisk enabled Clouds, using,
   - **Package Manifest** and **Deployment File(s)**.

Catalogs (Object Storage)

Package Manifest Files

Deployment File A

Deployment File B

OpenWhisk Serverless Cloud A

OpenWhisk Serverless Cloud B

143

144 **Notes**

145 • Deployment Files are optional. Deployment can be fully accomplished with simply the Manifest File.

146 # Composition

147 ## Action Sequence

148 An Action that is a sequenced composition of 2 or more existing Actions. The Action Sequence can be
149 viewed as a named pipe where OpenWhisk can automatically take the output of a first Action 'A' in a
150 declared sequence and provides it as input to the next Action 'B' in the sequence and so on until the
151 sequence completes.
152
153 *Note: This composition technique allows the reuse of existing action implementations treating them as*
154 *"building blocks" for other Actions.*

155 # Namespacing

156 Every OpenWhisk entity (i.e., Actions, Feeds, Triggers), including packages, belongs in a *namespace*.

157 The fully qualified name of any entity has the format:

```
/<namespaceName>[/<packageName>]/<entityName>
```

158

159 The namespace is typically provided at bind-time by the user deploying the package to their chosen
160 OpenWhisk platform provider.
161
162 *Note: The `/whisk.system` namespace is reserved for entities that are distributed with the OpenWhisk*
163 *system.*

Entity Names

165 The names of all entities, including actions, triggers, rules, packages, and namespaces, are a sequence of
166 characters that follow the following format:
167 • The first character SHALL be an alphanumeric character, a digit, or an underscore.
168 • The subsequent characters MAY be alphanumeric, digits, spaces, or any of the following:
169   `_, @, ., -`
170 • The last character SHALL NOT be a space.
171 • The maximum name length of any entity name is 256 characters (i.e., ENTITY_NAME_MAX_LENGTH =
172   256).

173 Valid entity names are described with the following regular expression (Java metacharacter
174 syntax):

```
"\A([\w]|[\w][\w@ .-]{0,${ENTITY_NAME_MAX_LENGTH - 2}}[\w@.-])\z"
```

Definitions

Activation

177 An invocation or "run" of an action results in an activation record that is identified by a unique activation
178 ID. The term Activation is short-hand for the creation of this record and its information.

Repository

180 A location that provides storage for sets of files, as well as the history of changes made to those files.

Project

182 A description of a software application which enables management of its design, implementation, source
183 control, monitoring and testing.

Application

185 A computer program designed to perform a group of coordinated functions, tasks, or activities to
186 achieve some result or user benefit.

[Cloud] Service

188 Any resource, including a functional task, that is provided over the Internet. This includes delivery
189 models such as *Platform as a Service* (PaaS), *Infrastructure as a* Service (IaaS), as well as *Serverless*.

Specification

191 This specification utilizes the YAML language, a superset of JSON, which supports key features for
192 packaging descriptors and configuration information such as built-in data types, complex data types,

193 anchors (relational information), files, comments and can embed other data formats such as JSON and
194 XML easily.

YAML Types

196 Many of the types we use in this profile are *built-in* types from the YAML 1.2 specification (i.e., those
197 identified by the "tag:yaml.org,2002" version tag).
198
199 The following table declares the valid YAML type URIs and aliases that SHALL be used when defining
200 parameters or properties within an OpenWhisk package manifest:
201

Type Name	Type URI	Notes
string	tag:yaml.org,2002:str (default)	Default type if no type provided
integer	tag:yaml.org,2002:int	Signed. Includes large integers (i.e., long type)
float	tag:yaml.org,2002:float	Signed. Includes large floating point values (i.e., double type)
boolean	tag:yaml.org,2002:bool	This specification uses lowercase 'true' and lowercase 'false'
timestamp	tag:yaml.org,2002:timestamp (see YAML-TS-1.1)	ISO 8601 compatible.
null	tag:yaml.org,2002:null	Different meaning than an empty string, map, list, etc.

202 *Requirements*

203 • The 'string' type SHALL be the default type when not specified on a parameter or property
204 declaration.
205 • All 'boolean' values SHALL be lowercased (i.e., 'true' or 'false').

OpenWhisk Types

207 In addition to the YAML built-in types, OpenWhisk supports the types listed in the table below. A
208 complete description of each of these types is provided below.
209

Type Name	Description	Notes
version	tag:maven.apache.org:version (see Maven version)	Typically found in modern tooling (i.e., "package@version" or "package:version" format).
string256	long length strings (e.g., descriptions)	A string type limited to 256 characters.
string64	medium length strings (e.g., abstracts, hover text)	A string type limited to 64 characters.
string16	short length strings (e.g., small form-factor list displays)	A string type limited to 16 characters.
json	The parameter value represents a JavaScript Object Notation (JSON) data object.	The deploy tool will validate the corresponding parameter value against JSON schema. Note: The implied schema for JSON the JSON Schema (see http://json-schema.org/).

scalar-unit	Convenience type for declaring common scalars that have an associated unit. For example, "10 msec.", "2 Gb", etc.)	Currently, the following scalar-unit subtypes are supported: • scalar-unit.size • scalar-unit.time See description below for details.
schema	The parameter itself is an OpenAPI Specifcation v2.0 **Schema Object** (in YAML formatt) with self-defining schema.	The schema declaration follows the OpenAPI v2.0 specification for Schema Objects (YAML format).. Specifically, see https://github.com/OAI/OpenAPI-Specification/blob/master/versions/2.0.md#schemaObject
object	The parameter itself is an object with the associated defined Parameters (schemas).	Parameters of this type would include a declaration of its constituting Parameter schema.

210

scalar-unit types

212 Scalar-unit types can be used to define scalar values along with a unit from the list of recognized units (a
213 subset of GNU units) provided below.

214 *Grammar*

```
<scalar> <unit>
```

215 In the above grammar, the pseudo values that appear in angle brackets have the following meaning:

216 • `scalar`: is a required scalar value (e.g., integer).
217 • `unit`: is a required unit value. The unit value MUST be type-compatible with the scalar value.

218 *Requirements*

219 • Whitespace: any number of spaces (including zero or none) SHALL be allowed between the scalar
220 value and the unit value.
221 • It SHALL be considered an error if either the scalar or unit portion is missing on a property or
222 attribute declaration derived from any scalar-unit type.

223 *Recognized units for sizes (i.e., scalar-unit.size)*

Unit	Description
B	byte
kB	kilobyte (1000 bytes)
MB	megabyte (1000000 bytes)
GB	gigabyte (1000000000 bytes)
TB	terabyte (1000000000000 bytes)

224 *Example*

```
inputs:
  memory_size:
    type: scalar-unit.size
```

```
    value: 256 MB
```

Recognized units for times (i.e., scalar-unit.time)

Unit	Description
d	days
h	hours
m	minutes
s	seconds
ms	milliseconds
us	microseconds

Example

```
inputs:
  max_execution_time:
    type: scalar-unit.time
    value: 600 s
```

Object type example

228
229 The Object type allows for complex objects to be declared as parameters with an optional validatable schema.

```
inputs:
  person:
    type: object
    parameters: <schema>
```

230

Schema

This section defines all the essential schema used to describe OpenWhisk packages within a manifest.

General Requirements

• All field names in this specification SHALL be case sensitive.

map schema

The Map schema is used to define maps of key values within OpenWhisk entities.

Single-line grammar

```
{ <key_1>: <value_1>, ..., <key_n>: <value_n> }
```

Multi-line grammar

```
# Where 'key_n' is a type <string> and 'value_n' is type <any>.
<key_1>: <value_1
...
```

```
<key_n>: <value_n>
```

239 *Examples*

240 *Single-line*

```
alert_levels: { "high": "red", "medium": "yellow", "low": green }
```

241 *Multi-line*

```
alert_levels:
  "high": "red"
  "medium": "yellow"
  "low": green
```

242

243 **Parameter schema**

244 The Parameter schema is used to define input and/or output data to be used by OpenWhisk entities for the
245 purposes of validation.

246 *Fields*

Key Name	Required	Value Type	Default	Description
type	no	<any>	string	Optional valid type name or the parameter's value for validation purposes. By default, the type is string.
description	no	string256	N/A	Optional description of the Parameter.
value	no	<any>	N/A	The optional user supplied value for the parameter. Note: this is not the default value, but an explicit declaration which allows simple usage of the Manifest file without a Deployment file..
required	no	boolean	true	Optional indicator to declare the parameter as required (i.e., true) or optional (i.e., false).
default	no	<any>	N/A	Optional default value for the optional parameters. This value **MUST** be type compatible with the value declared on the parameter's type field.
status	no	string	supported	Optional status of the parameter (e.g., deprecated, experimental). By default a parameter is without a declared status is considered supported.
schema	no	<schema>	N/A	The optional schema if the 'type' key has the value 'schema'. The value would include a **Schema Object** (in YAML) as defined by the OpenAPI Specfcation v2.0. This object is based upon the JSON Schema Specification.
properties	no	<list of Parameter schema>	N/A	The optional properties if the 'type' key has the value 'object'. Its value is a listing of Parameter schema from this specifcation.

247 *Requirements*

- The "schema" key's value MUST be compatible with the value provided on both the "type" and "value"
249 keys; otherwise, it is considered an error.

250 *Notes*

- The "type" key acknowledges some popular schema (e.g., JSON) to use when validating the value of
252 the parameter. In the future additional (schema) types may be added for convenience.

253 *Grammar*

254 *Single-line*

```
<parameterName>: <YAML type> | scalar-unit | json
```

- Where `<YAML type>` is inferred to be a YAML type as shown in the YAML Types section
256 above (e.g., string, integer, float, boolean, etc.).

- If you wish the parser to validate against a different schema, then the multi-line grammar
258 MUST be used where the value would be supplied on the keyname "value" and the type (e.g.,
259 json) and/or schema (e.g., OpenAPI) can be supplied

260 *Multi-line*

```
<parameterName>:
  type: <any>
  description: <string>
  required: <boolean>
  default: <any>
  status: <string>
  schema: <OpenAPI Schema Object>
```

261 *Status values*

Status Value	Description
supported (default)	Indicates the parameter is supported. This is the implied default status value for all parameters.
experimental	Indicates the parameter MAY be removed or changed in future versions.
deprecated	Indicates the parameter is no longer supported in the current version and MAY be ignored.

262 Dollar Notation ($) schema for values

263 In the Deployment file, a parameter value may be set from the local execution environment by using the
264 dollar ($) notation to denote names of local environment variables which supply the value to be inserted
265 at execution time.

266 *Syntax*

```
<parameter>: $<local environment variable name>
```

267 *Example*

```
...
```

```
   inputs:
     userName: $DEFAULT_USERNAME
```

Requirements

• Processors or tooling that encounter ($) Dollar notation and are unable to locate the value in the
execution environment SHOULD resolve the value to be the default value for the type (e.g., an empty
string for type string).

Notes

• Processors or tooling that encounter ($) Dollar notation for values should attempt to locate the
corresponding named variables set into the local execution environment (e.g., where the tool was
invoked) and assign its value to the named input parameter for the OpenWhisk entity.
• This specification does not currently consider using this notation for other than simple data types
(i.e., we support this mechanism for values such as strings, integers, floats, etc.) at this time.

Shared schema for all Entities

The entity schema contains fields that are common to all OpenWhisk entities (e.g., Actions, Triggers,
Rules, etc.).

Fields

Key Name	Required	Value Type	Default	Description
description	no	string256	N/A	The optional description for the Entity.
displayName	no	string16	N/A	This is the optional name that will be displayed on small form-factor devices.
annotations	no	map of strings	N/A	The optional annotations for the Entity.

Grammar

```
description: <string256>
displayName: <string16>
annotations: <map of <string>>
```

Requirements

• Non-required fields MAY be stored as "annotations" within the OpenWhisk framework after they
have been used for processing.
• Description string values SHALL be limited to 256 characters.
• DisplayName string values SHALL be limited to 16 characters.
• Annotations MAY be ignored by target consumers of the Manifest file as they are considered data
non-essential to the deployment of management of OpenWhisk entities themselves.
• Target consumers MAY preserve (persist) these values, but are not required to.
• For any OpenWhisk Entity, the maximum size of all Annotations SHALL be 256 characters.

292   *Notes*

293   • Several, non-normative Annotation keynames and allowed values for (principally for User Interface
294   (UI) design) may be defined below for optional usage.

Action entity

296   The Action entity schema contains the necessary information to deploy an OpenWhisk function and
297   define its deployment configurations, inputs and outputs.

298   *Fields*

Key Name	Required	Value Type	Default	Description
version	no	`version`	N/A	The optional user-controlled version for the Action.
function	yes	`string`	N/A	Required source location (path inclusive) of the Action code either • Relative to the Package manifest file. • Relative to the specified Repository.
runtime	no	`string`	N/A	The required runtime name (and optional version) that the Action code requires for an execution environment. *Note: May be optional if tooling allowed to make assumptions about file extensions.*
inputs	no	`list` of `parameter`	N/A	The optional ordered list inputs to the Action.
outputs	no	`list` of `parameter`	N/A	The optional outputs from the Action.
limits	no	`map` of limit keys and values	N/A	Optional map of limit keys and their values. *See section "Valid limit keys" below for a listing of recognized keys and values.*
feed	no	`boolean`	`false`	Optional indicator that the Action supports the required parameters (and operations) to be run as a Feed Action.
web-export	no	`boolean`	`false`	Optionally, turns the Action into a "*web actions*" causing it to return HTTP content without use of an API Gateway.

299   *Requirements*

300   • The Action name (i.e., `<actionName>` MUST be less than or equal to 256 characters.
301   • The Action entity schema includes all general Entity Schema fields in addition to any fields declared
302   above.
303   • Supplying a `runtime` name without a version indicates that OpenWhisk SHOULD use the most
304   current version.
305   • Supplying a runtime *major version* without a *minor version* (et al.) indicates OpenWhisk SHOULD use
306   the most current *minor version*.
307   • Unrecognized `limit` keys (and their values) SHALL be ignored.
308   • Invalid values for known `limit` keys SHALL result in an error.

309 • If the Feed is a Feed Action (i.e., the `feed` key's value is set to `true`), it MUST support the following
310   parameters:
311   • **lifecycleEvent**: one of 'CREATE', 'DELETE', 'PAUSE', or 'UNPAUSE'
312   ○ These operation names MAY be supplied in lowercase (i.e., 'create', 'delete', 'pause', etc.).
313   • **triggerName**: the fully-qualified name of the trigger which contains events produced from this
314   feed.
315   • **authKey**: the Basic auth. credentials of the OpenWhisk user who owns the trigger.

316 *Notes*

317 • Input and output parameters are implemented as JSON Objects within the OpenWhisk framework.
318 • The maximum code size for an Action currently must be less than 48 MB.
319 • The maximum payload size for an Action (i.e., POST content length or size) currently must be less
320   than 1 MB.
321 • The maximum parameter size for an Action currently must be less than 1 MB.
322 • if no value for runtime is supplied, the value 'language:default' will be assumed.

323 *Grammar*

```
# Note: the optional [.<type>] grammar is used for naming Web Actions.
<actionName>[.<type>]:
  <Entity schema>
  version: <version>
  function: <string>
  runtime: <name>[@<[range of ]version>]
  inputs:
    <list of Parameter>
  outputs:
    <list of Parameter>
  limits:
    <list of limit key-values>
  feed: <boolean> # default: false
  web-export: <boolean>
```

324 *Example*

```
my_awesome_action:
  version: 1.0
  description: An awesome action written for node.js
  function: src/js/action.js
  runtime: nodejs@>0.12<6.0
  inputs:
    not_awesome_input_value:
      description: Some input string that is boring
      type: string
  outputs:
    awesome_output_value:
      description: Impressive output string
      type: string
  limits:
    memorySize: 512 kB
    logSize: 5 MB
```

325 *Valid Runtime names*

326 The following runtime values are currently supported by the OpenWhisk platform.
327
328 Each of these runtimes also include additional built-in packages (or libraries) that have been determined
329 be useful for Actions surveyed and tested by the OpenWhisk platform.
330
331 These packages may vary by OpenWhisk release; examples of supported runtimes as of this specification
332 version include:
333

Runtime value	OpenWhisk kind	image name	Description
`nodejs`	nodejs	nodejsaction:latest	Latest NodeJS runtime
`nodejs@6`	nodejs:6	nodejs6action:latest	Latest NodeJS 6 runtime
`java, java@8`	java	java8action:latest	Latest Java language runtime
`python, python@2`	python:2	python2action:latest	Latest Python 2 language runtime
`python@3`	python:3	python3action:latest	Latest Python 3 language runtime
`swift, swift@2`	swift	swiftaction:latest	Latest Swift 2 language runtime
`swift@3`	swift:3	swift3action:latest	Latest Swift 3 language runtime
`swift@3.1.1`	swift:3.1.1	action-swift-v3.1.1:latest	Latest Swift 3.1.1 language runtime
`php`	php:7.1	action-php-v7.1:latest	Latest PHP language runtime
`language:default`	N/A	N/A	Permit the OpenWhisk platform to select the correct default language runtime.

334 *Recognized File extensions*

335 Although it is best practice to provide a runtime value when declaring an Action, it is not required. In
336 those cases, that a runtime is not provided, the package tooling will attempt to derive the correct runtime
337 based upon the the file extension for the Action's function (source code file). The following file
338 extensions are recognized and will be run on the latest version of corresponding Runtime listed below:
339

File extension	Runtime used	Description
`.js`	nodejs	Latest Node.js runtime.
`.java`	java	Latest Java language runtime.
`.py`	python	Latest Python language runtime.
`.swift`	swift	Latest Swift language runtime.
.php	php	Latest PHP language runtime.

340   *Valid Limit keys*

Limit Keyname	Allowed values	Default value	Valid Range	Description
`timeout`	scalar-unit.time	60000 ms	[100 ms, 300000 ms]	The per-invocation Action timeout. Default unit is assumed to be milliseconds (ms).
`memorySize`	scalar-unit.size	256 MB	[128 MB, 512 MB]	The per-Action memory. Default unit is assumed to be in megabytes (MB).
`logSize`	scalar-unit.size	10 MB	[0 MB, 10 MB]	The action log size. Default unit is assumed to be in megabytes (MB).
`concurrentActivations`	integer	1000	*See description*	The maximum number of concurrent Action activations allowed (per-namespace). *Note: This value is not changeable via APIs at this time.*
`userInvocationRate`	integer	5000	*See description*	The maximum number of Action invocations allowed per user, per minute. *Note: This value is not changeable via APIs at this time.*
`codeSize`	scalar-unit.size	48 MB	*See description*	The maximum size of the Action code. *Note: This value is not changeable via APIs at this time.*
`parameterSize`	scalar-unit.size	1 MB	*See description*	The maximum size *Note: This value is not changeable via APIs at this time.*

341   *Notes*

342   The default values and ranges for limit configurations reflect the defaults for the OpenWhisk platform
343   (open source code). These values may be changed over time to reflect the open source community
344   consensus.

345   *Web Actions*

346   OpenWhisk can turn any Action into a "web action" causing it to return HTTP content without use of an
347   API Gateway. Simply supply a supported "type" extension to indicate which content type is to be
348   returned and indentified in the HTTP header (e.g., `.json`, `.html`, `.text` or `.http`).

349   Return values from the Action's function are used to construct the HTTP response. The following
350   response parameters are supported in the response object.

351   • `headers`: a JSON object where the keys are header-names and the values are string values for
352   those headers (default is no headers).
353   • `code`: a valid HTTP status code (default is 200 OK).
354   • `body`: a string which is either plain text or a base64 encoded string (for binary data).

355 ***Trigger entity***

356 The Trigger entity schema contains the necessary information to describe the stream of events that it
357 represents. For more information see: "Creating Triggers and Rules".

358 *Fields*

Key Name	Required	Value Type	Default	Description
feed	no	`string`	N/A	The optional name of the Feed associated with the Trigger.
credential	no	`Credential`	N/A	The optional credential used to acces the feed service.
inputs	no	`list` of `parameter`	N/A	The optional ordered list inputs to the feed.
events	no	`list` of `Event`	N/A	The optional list of valid Event schema the trigger supports. OpenWhisk would validate incoming Event data for conformance against any Event schema declared under this key. ***Note****: This feature is <u>not supported at this time</u>. This is viewed as a possible feature that may be implemented along with configurable options for handling of invalid events.*

359 *Requirements*

360 • The Trigger name (i.e., `<triggerName>` MUST be less than or equal to 256 characters.
361 • The Trigger entity schema includes all general Entity Schema fields in addition to any fields declared
362   above.

363 *Notes*

364 • The '`events`' key name is not supported at this time.
365 • The Trigger entity within the OpenWhisk programming model is considered outside the scope of the
366   Package (although there are discussions about changing this in the future). This means that Trigger
367   and API information will not be returned when using the OpenWhisk Package API:
368   • `wsk package list <package name>`
369 • However, it may be obtained using the Trigger API:
370   • `wsk trigger list -v`

371 *Grammar*

```
<triggerName>:
  <Entity schema>
  feed: <feed name>
  credential: <Credential>
  inputs:
    <list of Parameter>
```

372 ***Rule entity***

373 The Rule entity schema contains the information necessary to associates one trigger with one action, with
374 every firing of the trigger causing the corresponding action to be invoked with the trigger event as input.
375 For more information see: "Creating Triggers and Rules".

Fields

Key Name	Required	Value Type	Default	Description
trigger	yes	`string`	N/A	Required name of the Trigger the Rule applies to.
action	yes	`string`	N/A	Required name of the Action the Rule applies to.
rule	no	`regex`	true	The optional regular expression that determines if the Action is fired. Note: In this version of the specification, only the expression "`true`" is currently supported.

Requirements

• The Rule name (i.e., `<ruleName>`) MUST be less than or equal to 256 characters.
• The Rule entity schema includes all general Entity Schema fields in addition to any fields declared
above.

Grammar

```
<ruleName>:
  description: <string>
  trigger: <string>
  action: <string>
  rule: <regex>
```

Example

```
my_rule:
  desription: Enable events for my Action
  trigger: my_trigger
  action: my_action
```

Feed entity

The OpenWhisk Feed entity schema contains the information necessary to reference a configurable
service that works with an existing network accessible service to produce events on its behalf thereby
acting as an Event Source.
These are standalone services unto themselves which the OpenWhisk platform does not currently deploy
and run from an OpenWhisk Package. At this time, the Package Manifest simply provides the information
to access, configure and manage (via lifecycle operations) the Feed service that is already running
elsewhere.

Fields

Key Name	Required	Value Type	Default	Description
location	no	string	N/A	The URL for the Feed service which can be used by the OpenWhisk platform or registration and conifguration.

Key Name	Required	Value Type	Default	Description
credential	no	string	N/A	Contains either: • A credential string. • The optional name of a credential (e.g., token) that must be used to acceess the Feed service. Note: this would be defined elsewhere, perhaps as an input parameter to the Package.
operations	no	list of operations	N/A	The list of operations (i.e., APIs) the Feed supports on the URL provided described, by default, using the OpenAPI (f.k.a. "Swagger") specification schema.
operation_type	no	openwhisk | openapi@<version>	openwhisk	The specification format for the operation definitions.
action	no	string	N/A	The optional name of the Action if this is a Feed Action, that is, the Feed service implementaion is an OpenWhisk Action.

393　*Requirements*

394　　• The Feed name (i.e., `<feedName>` MUST be less than or equal to 256 characters.
395　　• The Feed entity schema includes all general Entity Schema fields in addition to any fields declared
396　　　above.
397　　• If the `action` field is set, the corresponding Action defintion and function (code) MUST be a valid
398　　　Feed Action.
399　　• The location and credential SHOULD be supplied if the Feed is not a Feed action from the Deployment
400　　　File.
401　　• Operation names in manifests MAY be lower or upper cased (e.g., "create" or "CREATE").

402　*Grammar*

```
<feedName>:
  location: <string>
  credential: <Credential>
  operations:
    <list of operations>
  action: <string>
```

403　*Example*

404　The following example shows the mandatory operations for Feed Actions.
405

```
my_feed:
  description: A simple event feed
  location: https://my.company.com/services/eventHub
  # Reference to a credential defined elsewhere in manifest
  credential: my_credential
  operations:
    # Note: operation names in manifests MAY be lower or upper cased.
    create | CREATE:
      inputs:
        <parameters>
```

```
      delete | DELETE:
        inputs:
          <parameters>
      pause | PAUSE:
        inputs:
          <parameters>
      unpause | UNPAUSE:
        inputs:
          <parameters>
      # Additional, optional operations
      ...
```

406 *Discussion*

407 For a description of types of Feeds and why they exist, please see:

408 • https://github.com/apache/incubator-openwhisk/blob/master/docs/feeds.md.

409 *Feed Actions*

410 OpenWhisk supports an open API, where any user can expose an event producer service as a **feed** in a
411 **package**. This section describes architectural and implementation options for providing your own feed.

412 *Feed actions and Lifecycle Operations*

413 The *feed action* is a normal OpenWhisk *action*, but it should accept the following parameters:

414 • **lifecycleEvent**: one of 'CREATE', 'DELETE', 'PAUSE', or 'UNPAUSE'
415 • **triggerName**: the fully-qualified name of the trigger which contains events produced from this feed.
416 • **authKey**: the Basic auth. credentials of the OpenWhisk user who owns the trigger just mentioned

417 The feed action can also accept any other parameters it needs to manage the feed. For example, the
418 Cloudant changes feed action expects to receive parameters including *'dbname'*, *'username'*, etc.

419 **Sequence entity**

420 Actions can be composed into seqences to, in effect, form a new Action. The Sequence entity allows for
421 a simple, convenient way to describe them in the Package Manifest.

422 *Fields*

Key Name	Required	Value Type	Default	Description
actions	yes	list of Action	N/A	• The required list of two or more actions

423 *Requirements*

424 • The comma separated list of Actions on the actions key SHALL imply the order of the sequence (from
425   left, to right).
426 • There MUST be two (2) or more actions declared in the sequence.

427 *Notes*

428 • The sequences key exists for convenience; however, it is just one possible instance of a composition
429   of Actions. The composition entity is provided for not only describing sequences, but also for other
430   (future) compositions and additional information needed to compose them. For example, the

431   composition entity allows for more complex mappings of input and output parameters between
432   Actions.

433   *Grammar*

```
sequences:
  <sequence name>:
    <Entity schema>
    actions: <ordered list of action names>
  ...
```

434   *Example*

```
sequences:
  newbot:
    actions: oauth/login, newbot-setup, newbot-greeting
```

435   **API entity**

436   This entity allows manifests to link Actions to be made available as HTTP-based API endpoints as
437   supported by the API Gateway service of OpenWhisk.

438   This entity declaration is intended to provide grammar for the experimental API *(see*
439   *https://github.com/apache/incubator-openwhisk/blob/master/docs/apigateway.md* and shown using a
440   "book club" example:

441   *CLI Example*

```
$ wsk api create -n "Book Club" /club /books get getBooks
$ wsk api create /club /books post postBooks
$ wsk api create /club /books put putBooks
$ wsk api create /club /books delete deleteBooks
```

442   the above would translate to the following grammars in the pkg. spec. to a new-top level keyname "apis"
443   in the manifest:

444   *Grammar*

```
apis:
  <API name>:                    # descriptive name
    description: <string>        # optional, description
    <basepath>:                  # shared basepath
      <path>:
        <action name>: get | post | put | delete
        ...
      ...
```

445   *Note*

446   • There can be more than one set of named <path> actions under the same <basepath>.

447 *Example*

448 A somewhat simplified grammar is also supported that allows single-line definition of Actions (names)
449 along with their HTTP verbs.

450

```
apis:
  book-club:
    club:
      books:
        getBooks: get
        postBooks: post
        putBooks: put
        deleteBooks: delete
      members:
        listMembers: get
```

451 *Requirements*

452 • The API entity's name (i.e., `<API Name>`) MUST be less than or equal to 256 characters.

453 *Notes*

454 • The API entity within the OpenWhisk programming model is considered outside the scope of the
455   Package. This means that API information will not be returned when using the OpenWhisk Package
456   API:
457   • `wsk package list <package name>`
458 • However, it may be obtained using the Trigger API:
459   • `wsk api list -v`

460 ## Package entity

461 The Package entity schema is used to define an OpenWhisk package within a manifest.

462 *Fields*

Key Name	Required	Value Type	Default	Description
version	yes	`version`	N/A	The required user-controlled version for the Package.
license	no	`string`	N/A	The required value that indicates the type of license the Package is governed by. The value is required to be a valid Linux-SPDX value. See https://spdx.org/licenses/.
credential	no	`string`	N/A	The optional Credential used for all entities within the Package. The value is either: Contains either: • A credential string. • The optional name of a credential (e.g., token) that is defined elsewhere.
dependencies	no	list of Dependency	N/A	The optional list of external OpenWhisk packages the manifest needs deployed before it can be deployed.

Key Name	Required	Value Type	Default	Description
repositories	no	list of `Repository`	N/A	The optional list of external repositories that contain functions and other artifacts that can be found by tooling.
actions	no	list of `Action`	N/A	Optional list of OpenWhisk Action entity definitions.
sequences	no	list of `Sequence`	N/A	Optional list of OpenWhisk Sequence entity definitions.
triggers	no	list of `Trigger`	N/A	Optional list of OpenWhisk Trigger entity definitions.
rules	no	list of `Rule`	N/A	Optional list of OpenWhisk Rule entity definitions.
feeds	no	list of `Feed`	N/A	Optional list of OpenWhisk Feed entity definitions.
apis	no	list of `API`	N/A	Optional list of API entity definitions.
compositions *(Not yet supported)*	no	list of `Composition`	N/A	Optional list of OpenWhisk Composition entity definitions.

Requirements

- The Package `name` MUST be less than or equal to 256 characters.
- The Package entity schema includes all general Entity Schema fields in addition to any fields declared above.
- A valid Package `license` value MUST be one of the Linux SPDX license values; for example: `Apache-2.0` or `GPL-2.0+`, or the value 'unlicensed'.
- Multiple (mixed) licenses MAY be described using using NPM SPDX license syntax.
- A valid Package entity MUST have one or more valid Actions defined.

Notes

- Currently, the 'version' value is not stored in Apache OpenWhisk, but there are plans to support it in the future.
- Currently, the '`license`' value is not stored in Apache OpenWhisk, but there are plans to support it in the future.
- The Trigger and API entities within the OpenWhisk programming model are considered outside the scope of the Package. This means that Trigger and API information will not be returned when using the OpenWhisk Package API:
    - `wsk package list <package name>`
- However, their information may be retrieved using respectively:
    - `wsk trigger list –v`
    - `wsk api list -v`

Grammar

```
<packageName>:
    <Entity schema>
    version: <version>
    license: <string>
```

```
      repositories: <list of Repository>
      actions: <list of Action>
      sequences: <list of Sequence>
      triggers: <list of Trigger>
      rules: <list of Rule>
      feeds: <list of Feed>
      apis: <list of API>
      compositions: <list of Composition> # Not yet supported
```

484   *Example*

```
my_whisk_package:
  description: A complete package for my awesome action to be deployed
  version: 1.2.0
  license: Apache-2.0
  actions:
    my_awsome_action:
      <Action schema>
  triggers:
    trigger_for_awesome_action:
      <Trigger schema>
  rules:
    rule_for_awesome_action>
      <Rule schema>
```

485   **Composition entity** *(Not yet supported)*

486   The Composition entity schema contains information to declare compositions of OpenWhisk Actions.
487   Currently, this includes Action Sequences where Actions can be composed of two or more existing
488   Actions.

489   *Fields*

Key Name	Required	Value Type	Default	Description
type	no	string	sequence	The optional type of Action composition. *Note: currently only 'sequence' is supported.*
inputs	no	list of parameter	N/A	The optional list of parameters for the Action composition (e.g., Action Sequence).
outputs	no	list of parameter	N/A	The optional outputs from the Entity.
sequence	no	ordered list of Action (names)	N/A	The optional expression that describes the connections between the Actions that comprise the Action sequence composition.

Key Name	Required	Value Type	Default	Description
parameterMappings	no	TBD	N/A	The optional expression that describes the mappings of parameter (names and values) betweens the outputs of one Action to the inputs of another Action. Note: Currently, mappings are not supported and JSON objects are passed between each Action in a sequence. At this time, it is assumed that the Actions in a sequence are designed to work together with no output to input mappings being performed by the OpenWhisk platform.

490 *Requirements*

491 • The Composition name (i.e., `<compositionName>` MUST be less than or equal to 256 characters.

492 • The Composition entity schema includes all general Entity Schema fields in addition to any fields
493   declared above.

494 *Grammar*

```
<compositionName>:
  <Entity schema> # Common to all OpenWhisk Entities
  type: <string>
  inputs:
    <list of Parameter>
  outputs:
    <list of Parameter>
  sequence:
    actions: <ordered list of action names>
  parameterMappings:
    # TBD. This is a future use case.
```

495 *Example: multi-line sequence*

```
my_action_sequence:
  type: sequence
  sequence:
    actions: action_1, action_2, action_3
  inputs:
    simple_input_string: string
  outputs:
    annotated_output_string: string
```

496 # Extended Schema

497 *Dependencies*

498 The dependencies section allows you to declare other OpenWhisk packages that your application or
499 project (manifest) are dependent on. A Dependency is used to declare these other packages which
500 deployment tools can use to automate installation of these pre-requisites.

Fields

Key Name	Required	Value Type	Default	Description
location	yes	`string`	N/A	The required location of the dependent package.
version	yes	`version`	N/A	The required version of the dependent package.
inputs	no	`list of Parameter`	N/A	The optional Inputs to the dependent package.

502 *Requirements*

503   • No additional requirements.

504 *Notes*

505   • The <package_name> is a local alias for the actual package name as decribed in the referenced
506   package. The referenced package would have its own Manifest file that would include its actual
507   Package name (and the one that would be used by the wskdeploy tool to replace the local alias).
508   • The 'version' parameter is currently used to specify a branch in GitHub and defaults to "master", this
509   behavior may change in upcoming releases of the specification.
510   • The experimental key name 'name' is only valid when the deprecated 'package' keyword has been
511   used instead of the favored key 'packages'. If it is used within the 'packages' structure, it will cause a
512   warning and be ignored as it is redundant to the <packageName>.

513 *Grammar*

```
<package name>:
  <Entity schema>
  location: <GitHub URL> |
  version: 1.0.1
  inputs:
    <list of Parameter>
```

514 *Example*

```
dependencies:
  status_update:
    location: github.com/myrepo/statusupdate
    version: 1.0
  database pkg:
    location: /whisk.system/couchdb
    inputs:
      dbname: MyAppsDB
```

515

516 **Repository**

517 A repository defines a named external repository which contains (Action) code or other artifacts package
518 processors can access during deployment.

519 *Fields*

Key Name	Required	Value Type	Default	Description
description	no	`string256`	N/A	Optional description for the Repository.
url	yes	`string`	N/A	Required URL for the Repository.
credential	no	`Credential`	N/A	Optional name of a Credential defined in the Package that can be used to access the Repository.

520

521 *Requirements*

522 • The Repository name (i.e., `<repositoryName>` MUST be less than or equal to 256 characters.

523 • Description string values SHALL be limited to 256 characters.

524 *Grammar*

525 *Single-line (no credential)*

```
<repositoryName>: <repository_address>
```

526 *Multi-line*

```
<repositoryName>:
  description: <string256>
  url: <string>
  credential: <Credential>
```

527 *Example*

```
my_code_repo:
  description: My project's code repository in GitHub
  url: https://github.com/openwhisk/openwhisk-package-rss
```

528

529 ***Credential***

530 A Credential is used to define credentials used to access network accessible resources. Fields

Key Name	Required	Value Type	Default	Description
protocol	no	`string`	N/A	Optional protocol name used to indicate the authorization protocol to be used with the Credential's token and other values.
tokenType	yes	`string`	password	Required token type used to indicate the type (format) of the token string within the supported types allowed by the protocol.
token	yes	`string`	N/A	Required token used as a credential for authorization or access to a networked resource.
description	no	`string256`	N/A	Optional description for the Credential.

Key Name	Required	Value Type	Default	Description
keys	no	`map` of `string`	N/A	Optional list of protocol-specific keys or assertions.

531

Requirements

533   •   The Credential name (i.e., `<credentialName>` MUST be less than or equal to 256 characters.

534   •   Description string values SHALL be limited to 256 characters.

535   *Valid protocol values*

Protocol Value	Valid Token Type Values	Description
`plain`	N/A	Basic (plain text) username-password (no standard).
`http`	basic_auth	HTTP Basic Authentication Protocol.
`xauth`	X-Auth-Token	HTTP Extended Authentication Protocol (base-64 encoded Tokens).
`oauth`	bearer	Oauth 2.0 Protocol
`ssh`	identifier	SSH Keypair protocol (e.g., as used in OpenStack)

536

537   *Grammar*

```
Credential:
  type: Object
  properties:
    protocol:
      type: string
      required: false
    tokenType:
      type: string
      default: password
    token:
      type: string
    keys:
      type: map
      required: false
      entry_schema:
        type: string
    user:
      type: string
      required: false
```

538   *Notes*

539   • The use of transparent user names (IDs) or passwords are not considered best practice.

540 *Examples*

541 *Plain username-password (no standardized protocol)*

```
inputs:
  my_credential:
    type: Credential
      properties:
        user: my_username
        token: my_password
```

542 *HTTP Basic access authentication*

```
inputs:
  my_credential:
    type: Credential
    description: Basic auth. where <username>:<password> are a single string
    properties:
      protocol: http
      token_type: basic_auth
      # Note: this would be base64 encoded before transmission by any impl.
      token: myusername:mypassword
```

543 *X-Auth-Token*

```
inputs:
  my_credential:
    type: Credential
    description: X-Auth-Token, encoded in Base64
    properties:
      protocol: xauth
      token_type: X-Auth-Token
      # token encoded in Base64
      token: 604bbe45ac7143a79e14f3158df67091
```

544 *OAuth bearer token*

```
inputs:
  my_credential:
    type: Credential
    properties:
      protocol: oauth2
      token_type: bearer
      # token encoded in Base64
      token: 8ao9nE2DEjr1zCsicWMpBC
```

545 *SSH Keypair*

```
inputs:
  my_ssh_keypair:
    type: Credential
    properties:
      protocol: ssh
      token_type: identifier
      # token is a reference (ID) to an existing keypair (already installed)
```

```
      token: <keypair_id>
```

546

Package Artifacts

Package Manifest File

549 The Package Manifest file is the primary OpenWhisk Entity used to describe an OpenWhisk Package and
550 all necessary **schema** and **file** information needed for deployment. It contains the Package entity schema
551 described above.

Deployment File

553 The Deployment file is used in conjunction with a corresponding Package Manifest file to provide
554 configuration information (e.g., input parameters, authorization credentials, etc.) needed to deploy,
555 configure and run an OpenWhisk Package for a target Cloud environment.
556 Fields
557
558 The manifest and Deployment files are comprised of the following entities:

Application

560 An optional, top-level key that describes a set of related Packages that together comprise a higher-order
561 application.

Fields

Key Name	Required	Value Type	Default	Description
version	no	version	N/A	The optional user-controlled version for the Application.
name	no	string256	N/A	The optional name of the application. Note: This key is only valid in the singular 'package' grammar.
namespace	no	string	N/A	The optional namespace for the application (and default namesapce for its packages where not specified).
credential	no	string	N/A	The optional credential for the application (and default credential for its packages where not specified).
package	maybe	package (singular)	N/A	The required package defintion when the key name 'packages' (plural) is not present.
packages	maybe	list of package (plural)	N/A	The required list of <u>one or more</u> package definitions when the key name 'package' (singular) is not present.

563

Grammar (singular)

```
application:
  vesion: <version>
```

```
    name: <string256>
    namespace: <string>
    credential: <string>
    package:
      <package definition>
```

565   *Grammar (plural)*

```
 application:
   version: <version>
   name: <string256>
   namespace: <string>
   credential: <string>
   packages:
     <list of package definitions>
```

566   *Requirements*

567   •   The keys under the application key (e.g., name, namespace, credential and packages) are only used in
568   a manifest or deployment file if the optional application key is used.
569   •   Either the key name 'package' (singular) or the key name 'packages' (plural) MUST be provided but
570   not both.
571   o   If the 'package' key name is provided, its value must be a valid package definition.
572   o   If the 'packages' key name is provided, its value must be one or more valid package
573   definitions.

574   *Notes*

575   •   Currently, the OpenWhisk platform does not recognize the Application entity as part of the
576   programming model; it exists as a higher order grouping concept only in this specification. Therefore,
577   there is no data stored within OpenWhisk for the Application entity.
578   •   The keyword 'package' and its singular grammar for declaring packages MAY be deprecated in future
579   versions of the specification.

580   *Example*

```
 application:
   name: greetings
   namespace: /mycompany/greetings/
   credential: 1234-5678-90abcdef-0000
   packages:
     helloworld:
       inputs:
         city: Boston
       actions:
         hello:
           inputs: # input bindings
             personName: Paul
     ...
```

581   *Example Notes*

- A common use would be to associate a namespace (i.e., a target namespace binding) or credential to an application and all included packages automatically inherit that namespace (if applied at that level) unless otherwise provided (similar to style inheritance in CSS).
- The application name would be treated as metadata, perhaps stored in the annotations for the contained entities.

Normative References

Tag	Description
RFC2119	S. Bradner, *Key words for use in RFCs to Indicate Requirement Levels*, http://www.ietf.org/rfc/rfc2119.txt, IETF RFC 2119, March 1997.
YAML-1.2	YAML, Version 1.2, 3rd Edition, Patched at 2009-10-01, Oren Ben-Kiki, Clark Evans, Ingy döt Net http://www.yaml.org/spec/1.2/spec.html
YAML-TS-1.1	Timestamp Language-Independent Type for YAML Version 1.1, Working Draft 2005-01-18, http://yaml.org/type/timestamp.html
Maven-Version	The version type is defined with the Apache Maven project's policy draft: https://cwiki.apache.org/confluence/display/MAVEN/Version+number+policy
OpenAPI-2.0	The OpenAPI (f.k.a. "Swagger") specification for defining REST APIs as JSON. https://github.com/OAI/OpenAPI-Specification/blob/master/versions/2.0.md
Linux-SPDX	Linux Foundation, SPDX License list https://spdx.org/licenses/
NPM-SPDX-Syntax	Node Package Manager (NPM) SPDX License Expression Syntax https://www.npmjs.com/package/spdx

Non-normative References

Tag	Description
OpenWhisk-API	OpenWhisk REST API which is defined as an OpenAPI document. https://raw.githubusercontent.com/openwhisk/openwhisk/master/core/controller /src/main/resources/whiskswagger.json
GNU-units	Size-type units are based upon a subset of those defined by GNU at http://www.gnu.org/software/parted/manual/html_node/unit.html
RFC 6838	Mime Type definitions in compliance with RFC 6838.
RFC 7231	HTTP 1.1. status codes are described in compliance with RFC 7231.
IANA-Status-Codes	HTTP Status codes as defined in the IANA Status Code Registry.
JSON Schema Specification	The built-in parameter type "json" references this specification. http://json-schema.org/

Scenarios and Use cases

Usage Scenarios

User background

The following assumptions about the users referenced in the usage scenarios:

- Experienced developer; knows Java, Node, SQL, REST principles and basic DevOps processes; uses IDEs to develop code locally.
- Limited exposure to Serverless, but interested in trying new technologies that might improve productivity.

Scenario 1: Clone and Create

Deploy an OpenWhisk app (project, set of entities, package, ...) discovered on github. The developer...

1. discovers an interesting git repo containing an OpenWhisk app (project, set of entities, package, ...)
2. clones the repo to local disk.
3. He pushes (deploys) it into one of his OpenWhisk namespaces
4. He checks out the app's behavior using OpenWhisk CLI or OpenWhisk UI

Notes

- while this scenario allows to use the manifest file as a "black box" the manifest format can influence the user experience of a developer trying to read it and understand what it does

Scenario 2: Pushing Updates with versioning

Change a cloned repo that he previously pushed into one of his namespaces. The developer...

1. changes the local repo by editing code and adding and changing entity specifications using local tools (editors, IDEs, ...).
2. bumps version number for package.
3. pushes his updates into the namespace so that the existing entities are changed accordingly.

Scenario 3: Start New Repo with Manifest

Start a new OpenWhisk app (project, set of entities) from scratch. The developer...

1. code files for the actions (e.g. *action1.js, action2.js, action3.js)*
2. creates a LICENSE.*txt file*
3. Creates a **Manifest File** that specifies the set of OpenWhisk entities and their relations (e.g. *manifest.yml).*   It also references the LICENSE.txt file.
4. initializes and uploads the set of files as a new git repo.

Notes:

626   •   Creating the initial manifest file should be supported by providing an empty template with syntax
627   examples and other helpful comments

628   ***Scenario 4: Export into Repository***

629   Share an existing OpenWhisk app (project, set of entities) with others
630   so that they can deploy and change it for their purposes. The developer…

631   1.   exports a defined set of entities (a whole namespace?) into a set of files that includes code files,
632   and generated manifest, LICENSE.txt and README files.
633   2.   initializes and uploads the set of files as a new git repo.
634   Example: `git init` … etc.

635   ***Scenario 5: Discovery and Import from object store***

636   Discover an OpenWhisk package (manifest) co-located with data in an Object storage service.

637   This package would include a description of the Actions, Triggers, Rules and Event Sources (or Feeds)
638   necessary to interact with data it is associated with directly from the Object storage repository; thus
639   allowing anyone with access to the data an immediate way to interact and use the data via the OpenWhisk
640   Serverless platform.

641

Guided examples

643 This section will use examples to incrementally show how to use the OpenWhisk Packaging Specification
644 to author increasingly more interesting Package Manifest and Deployment files.

Minimal valid Package Manifest

646 This use case shows a minimal valid package manifest file.
647
648 including:

649 • shows how to declare a Package named 'hello_world_package'.

Manifest Files

651 *Example 1: Miminum valid Package manifest file*

```
package:
  name: hello_world_package
  version: 1.0
  license: Apache-2.0
```

652 *Notes*

653 • Currently, the 'version' and 'license' key values are not stored in Apache OpenWhisk, but there are
654 plans to support it in the future.

"Hello world" using a JavaScript Action

656 This use case shows how to declare a basic "Hello world" Action using an OpenWhisk Package manifest.
657
658 This example:

659 • declare a single Action named 'hello_world' within the 'hello_world_package' Package.
660 • associate the JavaScript function's source code, stored in the file 'src/hello.js', to the 'hello_world'
661 Action.

Manifest File

663 *Example 1: "Hello world" using a NodeJS (JavaScript) action*

```
package:
  name: hello_world_package
  version: 1.0
  license: Apache-2.0
  actions:
    hello_world:
      function: src/hello.js
```

664

665 where "hello.js", within the package-relative subdirectory named 'src', contains the following
666 JavaScript code:

```
function main(params) {
    msg = "Hello, " + params.name + " from " + params.place;
    return { greeting:  msg };
}
```

667   *Discussion*

668   In the above example, tooling based upon this specification would:

669   • Deploy the package and its action to the user's default namespace using the 'package' name.
670   • /<default namespace>/hello_world_package/hello_world
671   • Default the runtime (i.e., `runtime: nodejs`) based upon the '.js' extension on the Action function's
672   filename.

673   ## "Hello world" with basic input and output parameters

674   This use case extends the "Hello world" example with explicit input and output Parameter declarations.
675
676   This example:

677   • shows how to declare input and output parameters on the action 'hello_world' using a simple,
678   single-line grammar.
679   • adds two input parameters, 'name' and 'place', both of type 'string' to the 'hello_world' action.
680   • adds one output parameter, 'greeting' of type string to the 'hello_world' action.

681   *Manifest File*

682   *Example 2: "Hello world" with explicit input and output parameter declarations*

```
package:
  name: hello_world_package
  ... # Package keys omitted for brevity
  actions:
    hello_world_2:
      function: src/hello.js
      inputs:
        name: string
        place: string
      outputs:
        greeting: string
```

683   *Discussion*

684   This packaging specification grammar places an emphasis on simplicity for the casual developer who may
685   wish to hand-code a Manifest File; however, it also provides a robust optional schema that can be
686   advantaged when integrating with larger application projects using design and development tooling such
687   as IDEs.
688
689   In this example:

690   • The default values for the 'name' and 'place' inputs would be set to empty strings (i.e., ""), since they
691   are of type 'string', when passed to the 'hello.js' function.

"Hello world" with full input and output parameters

This example builds on the previous "Hello world with basic input and output parameters" example with more robust input and output parameter declarations by using a multi-line format for declaration.

This example:

- shows how to declare input and output parameters on the action 'hello_world' using a multi-line grammar.
- adds the 'name' and 'place' input parameters, both of type 'string', to the 'hello_world' action each also includes an associated 'description' value.
- adds the 'greeting' output parameter of explicit 'type' of 'string' to the 'hello_world' action with a 'description'.

Simple grammar versus Full Input and Output Grammar

If we want to do more than declare the type (i.e., 'string', 'integer', 'float', etc.) of the input parameter, we can use the multi-line grammar.

Example 3: inputs and output parameters with explicit types and descriptions

```
package:
  name: hello_world_package
  ... # Package keys omitted for brevity
  actions:
    hello_world_3:
      function: src/hello/hello.js
      runtime: nodejs@6
      inputs:
        name:
          type: string
          description: name of person
        place:
          type: string
          description: location of person
      outputs:
        greeting:
          type: string
          description: greeting string
```

Adding a Trigger and Rule to "hello world"

This example will demonstrate how to define a Trigger that is compatible with the basic 'hello_world' Action and associate it using a Rule.

Manifest File

```
package:
  name: helloRules
  ... # Package keys omitted for brevity
  actions:
    hello_world:
      version: 1.0
      function: src/hello.js
```

```
    runtime: nodejs
    inputs:
      name: string
      place: string
    outputs:
      greeting: string

triggers:
  meetPerson:
    inputs:
      name: string
      place: string

rules:
  myRule:
    trigger: meetPerson
    action: hello_world
```

711 *Deployment File*

```
package:
  helloRules:
    triggers:
      meetPerson:
        inputs:
          name: Sam
          place: the Shire.
```

712

Github feed

714 This example will install a feed to fire a trigger when there is activity in a specified GitHub repository.

715 *Manifest File*

```
git_webhook:
  version: 1.0
  license: Apache-2.0
  feeds:
    webhook_feed:
      version: 1.0
      function: github/webhook.js
      runtime: nodejs@6
      inputs:
        username:
          type: string
          description: github username
        repository:
          type: string
          description: url of github repository
        accessToken:
          type: string
          description: GitHub personal access token
```

```
        events:
          type: string
          description: the github event type

    triggers:
      webhook_trigger:
        action: webhook_feed
```

716   *Deployment File*

```
packages:
  git_webhook:
    triggers:
      webhook_trigger:
        inputs:
          username: daisy
          repository: https://github.com/openwhisk/wsktool.git
          accessToken:
          events:push
```

717

Advanced examples

Github feed advanced

720   This use case use the Github feed to create a trigger. When there is any push event happened, it will send
721   a notification email.

722   *Manifest File*

```
git_webhook:
  version: 1.0
  license: Apache-2.0
  action:
    emailNotifier:
      version: 1.0
      function: src/sendemail.js
      runtime: nodejs
      inputs:
        email: string
        title: string
  rules:
    githubNotifier:
      trigger: webhook_trigger
      action: emailNotifier
```

723   *Deployment File*

```
packages:
  git_webhook:
    feeds:
      webhook_feed:
```
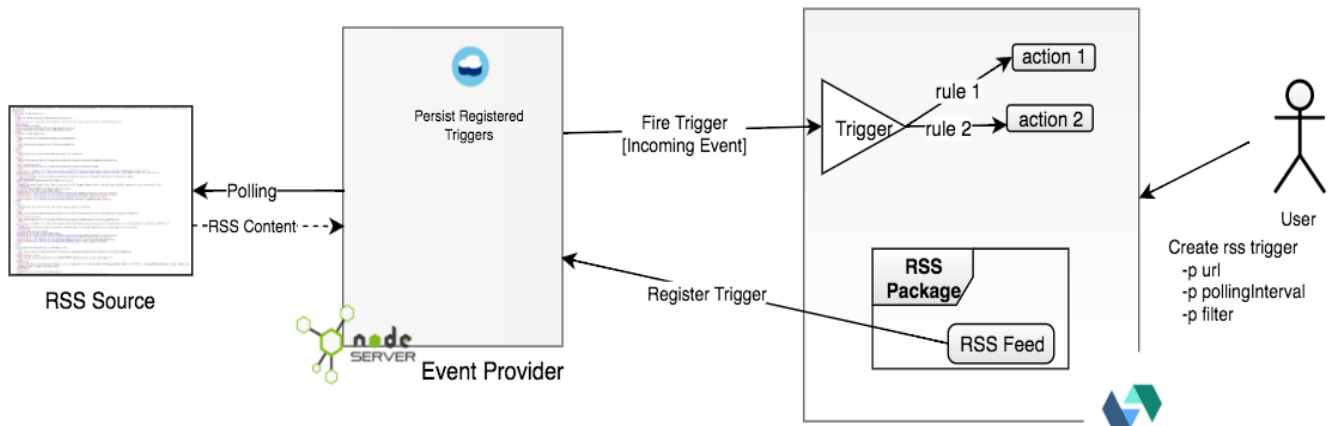
```
      inputs:
        email: daisy@company.com
        title: Github Push Notification
```

724

RSS Package

726 The RSS package provides RSS/ATOM feeds which can receive events when a new feed item is
727 available. It also defines a trigger to listen to a specific RSS feed. It describes the OpenWhisk package
728 reposited here:
729 https://github.com/openwhisk/openwhisk-package-rss.
730

731

Manifest File

with inline values (no Deployment File)

734 This example makes use of in-line "values" where the developer does not intend to use a separate
735 Deployment file:

```
rss:
  version: 1.0
  license: Apache-2
  description: RSS Feed package
  inputs:
    provider_endpoint:
      value: http://localhost:8080/rss
      type: string
      description: Feed provider endpoint

  feeds:
    rss_feed:
      version: 1.0
      function: feeds/feed.js
      runtime: nodejs@6
      inputs:
        url:
          type: string
          description: url to RSS feed
```

```
                value: http://rss.nytimes.com/services/xml/rss/nyt/HomePage.xml
             pollingInterval:
               type: string
               description: Interval at which polling is performed
               value: 2h
             filter:
               type: string
               description: Comma separated list of keywords to filter on

       triggers:
         rss_trigger:
           action: rss_feed
```

736

737 *Deployment File*

738 Alternatively, a Deployment File could have provided the same values (bindings) in this way:

```
packages:
  rss:
    inputs:
      provider_endpoint: http://localhost:8080/rss

    feeds:
      rss_feed:
        inputs:
          url: http://rss.nytimes.com/services/xml/rss/nyt/HomePage.xml
          pollingInterval: 2h
```

739
740 Using such a deployment file, allows for more flexibility and the resulting Manifest file would not have
741 needed any '**value**' fields.

Polygon Tracking

743 This use case describes a microservice composition using Cloudant and a Push Notification service to
744 enable location tracking for a mobile application. The composition uses Cloudant to store polygons that
745 describe regions of interests, and the latest known location of a mobile user. When either the polygon set
746 or location set gets updated, we use the Cloudant Geo capabilities to quickly determine if the new item
747 satisfies a geo query like "is covered by" or "is contained in". If so, a push notification is sent to the user.

748 *Manifest File:*

```
application:
  name: PolygonTracking
  namespace: polytrack

  packages:
    polytrack:

      triggers:
        pointUpdate:
          <feed>
```

```
    polygonUpdate:
      <feed>

actions:
  superpush:
    inputs:
      appId: string
      appSecret: string

  pointGeoQuery:
    inputs:
      username: string
      password: string
      host: string
      dbName: string
      ddoc: string
      iName: string
      relation: string
    outputs:
      cloudantResp: json

  createPushParamsFromPointUpdate:
    <mapper>

  polygonGeoQuery:
    inputs:
      username: string
      password: string
      host: string
      dbName: string
      ddoc: string
      iName: string
      relation: string
    outputs:
      cloudantResp: json

  createPushParamsFromPolygonUpdate:
    <mapper>

Rules:
  whenPointUpdate:
    trigger:
      pointUpdate
    action:
      handlePointUpdate
  whenPointUpdate:
    trigger:
      polygonUpdate
    action:
      handlePolygonUpdate

Composition:
  handlePolygonUpdate:
```

```
        sequence:
createGeoQueryFromPolygonUpdate,polygonGeoQuery,createPushParamsFromPolygo
nUpdate,superpush
```

749 *Deployment File:*

```
application:
  name: PolygonTracking
  namespace: polytrack

  packages:

    myCloudant:
      <bind to Cloudant at whisk.system/Cloudant>

    polytrack:
      credential: ABDCF
      inputs:
        PUSHAPPID=12345
        PUSHAPPSECRET=987654
        COVEREDBY='covered_by'
        COVERS='covers'
        DESIGNDOC='geodd'
        GEOIDX='geoidx'
        CLOUDANT_username=myname
        CLOUDANT_password=mypassword
        CLOUDANT_host=myhost.cloudant.com
        POLYDB=weatherpolygons
        USERLOCDB=userlocation

      triggers:
        pointUpdate:
          <feed>
          inputs:
            dbname: $USERLOCALDB
            includeDoc: true
        polygonUpdate:
          <feed>
          inputs:
            dbname: $USERLOCDB
            includeDoc: true

      actions:
        superpush:
          inputs:
            appId: $PUSHAPPID
            appSecret: $PUSHAPPSECRET
        pointGeoQuery:
```

```
        inputs:
          designDoc: $DESIGNDOC
          indexName: $GEOIDX
          relation: $COVEREDBY
          username: $CLOUDANT_username
          password: $CLOUDANT_password
          host: $CLOUDANT_host
          dbName: $POLYDB
      polygonGeoQuery:
        inputs:
          designDoc: $DESIGNDOC
          indexName: $GEOIDX
          relation: $COVERS
          username: $CLOUDANT_username
          password: $CLOUDANT_password
          host: $CLOUDANT_host
          dbName: $POLYDB
```

750

MQTT Package (tailored for Watson IoT)

751

752   The MQTT package that integrates with Watson IoT provides message topic feeds which can receive
753   events when a message is published. It also defines a trigger to listen to a specific MQTT topic It
754   describes the OpenWhisk package reposited here: https://github.com/krook/openwhisk-package-mqtt-
755   watson.
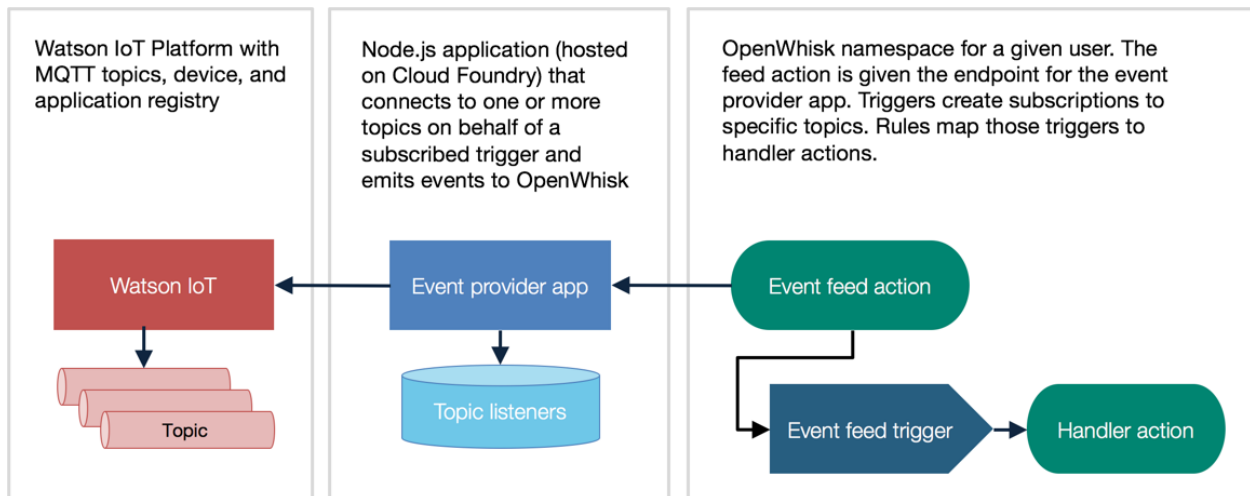
756

757
758

Manifest File

759

760   *with inline values (no Deployment File)*

761   This example makes use of in-line "values" where the developer does not intend to use a separate
762   Deployment file:

```
mqtt_watson:
```

```
      version: 1.0
      license: Apache-2
      description: MQTT Feed package for Watson IoT
      inputs:
        provider_endpoint:
          value: http://localhost:8080/mqtt-watson
          type: string
          description: Feed provider endpoint

      feeds:
        mqtt_watson_feed:
          version: 1.0
          function: feeds/feed-action.js
          runtime: nodejs@6
          inputs:
            url:
              type: string
              description: URL to Watson IoT MQTT feed
              value: ssl://a-123xyz.messaging.internetofthings.ibmcloud.com:8883
            topic:
              type: string
              description: Topic subscription
              value: iot-2/type/+/id/+/evt/+/fmt/json
            apiKey:
              type: string
              description: Watson IoT API key
              value: a-123xyz
            apiToken:
              type: string
              description: Watson IoT API token
              value: +-derpbog
            client:
              type: string
              description: Application client id
              value: a:12e45g:mqttapp


      triggers:
        mqtt_watson_trigger:
          action: mqtt_watson_feed
```

763

Deployment File

765   Alternatively, a Deployment File could have provided the same values (bindings) in this way:

```
packages:
  mqtt_watson:
    inputs:
      provider_endpoint: http://localhost:8080/mqtt-watson

    feeds:
      mqtt_watson_feed:
        inputs:
```

```
url: ssl://a-123xyz.messaging.internetofthings.ibmcloud.com:8883
topic: iot-2/type/+/id/+/evt/+/fmt/json
apiKey: a-123xyz
apiToken: +-derpbog
client: a:12e45g:mqttapp
```

766

767 Using such a deployment file, allows for more flexibility and the resulting Manifest file would not have
768 needed any '**value**' fields.

769

Check deposit processing with optical character recognition

770

771 This use case demonstrates an event-driven architecture that processes the deposit of checks to a bank
772 account using optical character recognition. It relies on Cloudant and SoftLayer Object Storage. On
773 premises, it could use CouchDB and OpenStack Swift. Other storage services could include FileNet or
774 Cleversafe. Tesseract provides the OCR library.

775

776 This application uses a set of actions and triggers linked by rules to process images that are added to an
777 object storage service. When new checks are detected a workflow downloads, resizes, archives, and reads
778 the checks then it invokes an external system to handle the transaction.

779

780

781 *Manifest File:*
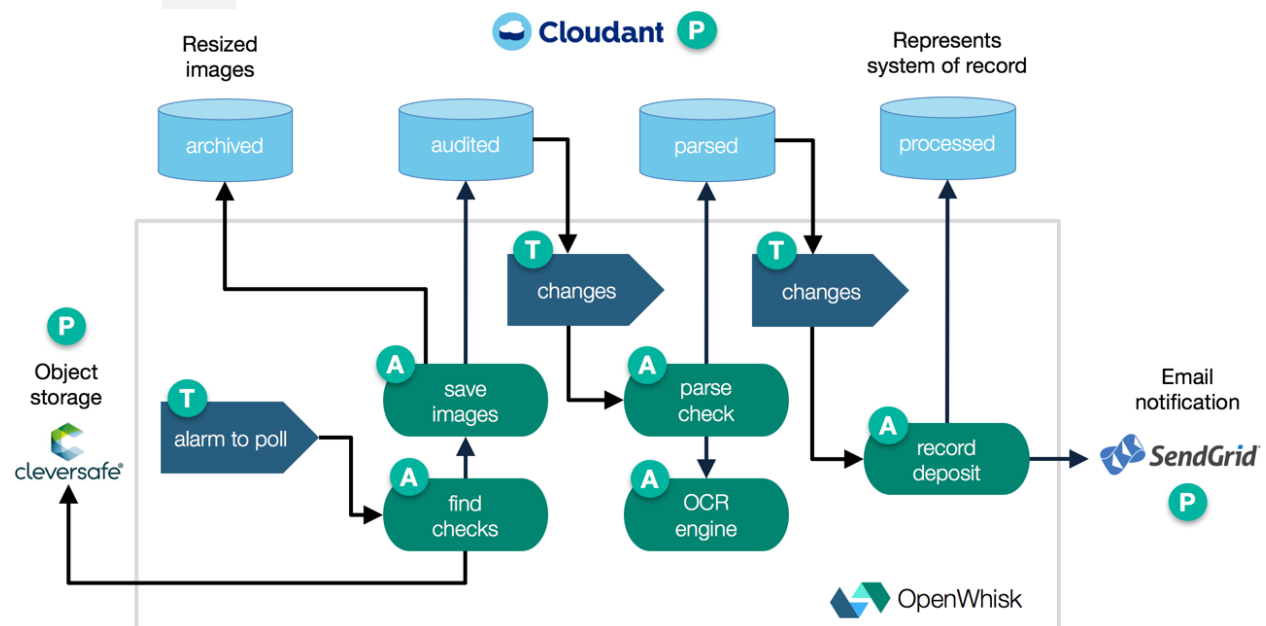
```yaml
application:
  name: OpenChecks
  namespace: openchecks

  packages:
    openchecks:

    triggers:
      poll-for-incoming-checks:
        inputs:
          cron: string
          maxTriggers: integer

      check-ready-to-scan:
        inputs:
          dbname: string
          includDocs: boolean

      check-ready-for-deposit:
        inputs:
          dbname: string
          includDocs: boolean

    actions:
      find-new-checks:
        inputs:
          CLOUDANT_USER: string
          CLOUDANT_PASS: string
          SWIFT_USER_ID: string
          SWIFT_PASSWORD: string
          SWIFT_PROJECT_ID: string
          SWIFT_REGION_NAME: string
          SWIFT_INCOMING_CONTAINER_NAME: string
          CURRENT_NAMESPACE: string

      save-check-images:
        inputs:
          CLOUDANT_USER: string
          CLOUDANT_PASS: string
          CLOUDANT_ARCHIVED_DATABASE: string
          CLOUDANT_AUDITED_DATABASE: string
          SWIFT_USER_ID: string
          SWIFT_PASSWORD: string
          SWIFT_PROJECT_ID: string
          SWIFT_REGION_NAME: string
          SWIFT_INCOMING_CONTAINER_NAME: string

      parse-check-data:
        inputs:
          CLOUDANT_USER: string
          CLOUDANT_PASS: string
          CLOUDANT_AUDITED_DATABASE: string
          CLOUDANT_PARSED_DATABASE: string
```

```
            CURRENT_NAMESPACE: string

        record-check-deposit:
          inputs:
            CLOUDANT_USER: string
            CLOUDANT_PASS: string
            CLOUDANT_PARSED_DATABASE: string
            CLOUDANT_PROCESSED_DATABASE: string
            CURRENT_NAMESPACE: string
            SENDGRID_API_KEY: string
            SENDGRID_FROM_ADDRESS: string

        parse-check-with-ocr:
          inputs:
            CLOUDANT_USER: string
            CLOUDANT_PASS: string
            CLOUDANT_AUDITED_DATABASE: string
            id: string
          outputs:
            result: JSON

      rules:
        fetch-checks:
          trigger:
            poll-for-incoming-checks
          action:
            find-new-checks
        scan-checks:
          trigger:
            check-ready-to-scan
          action:
            parse-check-data
        deposit-checks:
          trigger:
            check-ready-for-deposit
          action:
            record-check-deposit
```

782 ***Deployment File:***

```
application:
  name: OpenChecks
  namespace: openchecks

  packages:

    myCloudant:
      <bind to Cloudant at whisk.system/Cloudant>

    openchecks:
    credential: ABDCF
    inputs:
      XXX=YYY
```

```yaml
triggers:
  poll-for-incoming-checks:
    <feed>
    inputs:
      cron: */20 * * * * *
      maxTriggers: 90
  check-ready-to-scan:
    <feed>
    inputs:
      dbname: audit
      includeDoc: true
  check-ready-for-deposit:
    <feed>
    inputs:
      dbname: parsed
      includeDoc: true

actions:
  find-new-checks:
    inputs:
      CLOUDANT_USER: 123abc
      CLOUDANT_PASS: 123abc
      SWIFT_USER_ID: 123abc
      SWIFT_PASSWORD: 123abc
      SWIFT_PROJECT_ID: 123abc
      SWIFT_REGION_NAME: northeast
      SWIFT_INCOMING_CONTAINER_NAME: incoming
      CURRENT_NAMESPACE: user_dev
  save-check-images:
    inputs:
      CLOUDANT_USER: 123abc
      CLOUDANT_PASS: 123abc
      CLOUDANT_ARCHIVED_DATABASE: archived
      CLOUDANT_AUDITED_DATABASE: audited
      SWIFT_USER_ID: 123abc
      SWIFT_PASSWORD: 123abc
      SWIFT_PROJECT_ID: 123abc
      SWIFT_REGION_NAME: northeast
      SWIFT_INCOMING_CONTAINER_NAME: container_name
  parse-check-data:
    inputs:
      CLOUDANT_USER: 123abc
      CLOUDANT_PASS: 123abc
      CLOUDANT_AUDITED_DATABASE: audited
      CLOUDANT_PARSED_DATABASE: parsed
      CURRENT_NAMESPACE: user_dev
  record-check-deposit:
    inputs:
```

```
            CLOUDANT_USER: 123abc
            CLOUDANT_PASS: 123abc
            CLOUDANT_PARSED_DATABASE: parsed
            CLOUDANT_PROCESSED_DATABASE: processed
            CURRENT_NAMESPACE: user_dev
            SENDGRID_API_KEY: 123abc
            SENDGRID_FROM_ADDRESS: user@example.org
      parse-check-with-ocr:
        inputs:
            CLOUDANT_USER: 123abc
            CLOUDANT_PASS: 123abc
            CLOUDANT_AUDITED_DATABASE: audited
            id: 123abc
```

784 Event Sources

785 OpenWhisk is designed to work with any Event Source, either directly via published APIs from the Event
786 Source's service or indirectly through Feed services that act as an Event Source on behalf of a service.
787 This section documents some of these Event Sources and/or Feeds using this specification's schema.

788 Curated Feeds

789 The following Feeds are supported by the Apache OpenWhisk platform. They are considered "curated"
790 since they are maintained alongside the Apache OpenWhisk open source code to guarantee compatibility.
791 More information on curated feeds can be found here: https://github.com/apache/incubator-
792 openwhisk/blob/master/docs/feeds.md.

793 Alarms

794 The `/whisk.system/alarms` package can be used to fire a trigger at a specified frequency. This is
795 useful for setting up recurring jobs or tasks, such as invoking a system backup action every hour.

796 *Package Manifest*

797 The "alarms" Package Manifest would appear as follows:

798

```
# shared system package providing the alarms feed action
alarms:
  version: 1.0
  license: Apache-2
  description: Alarms and periodic utility

  actions:
    alarm:
      function: action/alarm.js
      description: Fire trigger when alarm occurs
      feed: true
      inputs:
        package_endpoint:
          type: string
          description: The alarm provider endpoint with port
        cron:
          type: string
          description: UNIX crontab syntax for firing trigger in
 Coordinated Universal Time (UTC).
          required: true
        trigger_payload:
          type: object
          description: The payload to pass to the Trigger, varies
          required: false
        maxTriggers:
          type: integer
          default: 1000
          required: false


  feeds:
```

```
location: TBD
credential: TBD
operations:
  CREATE:
    TBD
  DELETE:
    TBD
action: alarm
```

799
800

Cloudant

802 The `/whisk.system/cloudant` package enables you to work with a Cloudant database. It includes the
803 following actions and feeds.

Package Manifest

805 The "cloudant" Package Manifest would appear as follows:

TBD

Public Sources

807 The following examples are Event Sources that can provide event data to OpenWhisk. We describe them
808 here using this specification's schema.

GitHub WebHook

810 Note: the GitHub WebHook is documented here: https://developer.github.com/webhooks/.
811

812 A sample description of the GitHub Event Source and its "create hook" API would appear as follows:

TBD

813

Other Considerations

Tooling interaction

Using package manifest directly from GitHub

GitHub is an acknowledged as a popular repository for open source projects which may include OpenWhisk Packages along with code for Actions and Feeds. It is easily envisioned that the Package Manifest will commonly reference GitHub as a source for these artifacts; this specification will consider Github as being covered by the general Catalog use case.

Using package manifest in archive (e.g., ZIP) file

Compressed packaging, including popular ZIP tools, is a common occurrence for popular distribution of code which we envision will work well with OpenWhisk Packages; however, at this time, there is no formal description of its use or interaction. We leave this for future consideration.

Simplification of WebHook Integration

Using RESTify

One possible instance of a lightweight framework to build REST APIs in Nodejs to export WebHook functionality. See https://www.npmjs.com/package/restify
RESTify (over Express) provides help in the areas of versioning, error handling (retry, abort) and content-negotiation. It also provides built in DTrace probes that identify application performance problems.

Enablement of Debugging for DevOps

Isolating and debugging "bad" Actions using (local) Docker

Simulate Inputs at time of an Action failure/error condition, isolate it and run it in a "debug" mode.

Considerations include, but are not limited to:
- Isolation on separate "debug" container
- Recreates "inputs" at time of failure
- Possibly recreates message queue state
- Provides additional stacktrace output
- Provides means to enable "debug" trace output
- Connectivity to "other" debug tooling

Using software debugging (LLDB) frameworks

This is a topic for future use cases and integrations. Specifically, working with LLDB frameworks will be considered. See http://lldb.llvm.org/.

Acknowledgements