Microsoft Office Telemetry

Analysis report
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1 Introduction

ERNW GmbH was tasked by the German Federal Office for Information Security (orig. ger., Bundesamt für Sicherheit in der Informationstechnik (BSI)) with analyzing the output of telemetry data from Microsoft Office and provide recommendations on how to deactivate or minimize it (see Section 1.1 and Section 1.2).

1.1 Concepts and Terms

This section introduces concepts and terms relevant for better understanding the content of this work.

The Windows 10 operating system implements the concept of telemetry. This involves collecting and sending diagnostic data to a backend managed by Microsoft, referred to as the Microsoft backend, for storing and processing. Diagnostic data is a set of diagnostic events that log information on different aspects of the operation of Windows and applications running on it. This includes usage information as well as information relevant for diagnosing issues, such as application crash information.

Connected User Experiences and Telemetry is the central telemetry component of Windows 10. The Connected User Experiences and Telemetry service, also known as DiagTrack, is the core building block of the component. It is responsible for collecting and sending diagnostic events to Microsoft.

DiagTrack primarily relies on Event Tracing for Windows (ETW) [ms_etw] for collecting diagnostic events. ETW is the core logging mechanism of Windows. The architecture of ETW is composed of several components, some of which are ETW providers, ETW sessions, and ETW consumers. An ETW provider is a software entity that produces log data (events). ETW providers are implemented and declared as part of instrumented executables using the ETW application programming interface (API) [ms_eapi]. Each ETW provider can be uniquely identified by a globally unique identifier (GUID), a 128-bit number. ETW providers deliver data to ETW sessions. An ETW session is a software entity that receives data from the ETW providers associated with it and delivers this data to ETW consumers. An ETW consumer is software that consumes and processes (e.g., displays) the data delivered by ETW sessions. For example, the Event Viewer utility is an ETW consumer. ([ERNW_WP4], Section 1.3) documents the architecture of ETW in greater detail.

The DiagTrack service receives diagnostic data from two ETW sessions, Autologger-Diagtrack-Listener and Diagtrack-Listener. Autologger-Diagtrack-Listener is active during system initialization. Diagtrack-Listener delivers diagnostic events to DiagTrack in the form of a real-time feed during system operation. [ERNW_WP4] discusses the architecture and operational principles of Connected User Experiences and Telemetry in greater detail.

It is important to emphasize that not only Connected User Experiences and Telemetry, but also applications developed by Microsoft may produce and send diagnostic events to the Microsoft backend. An example is Microsoft 365 (formerly called Microsoft Office 365), referred to as Office in this work. An Office deployment on a Windows instance consists of Office applications, such as Word and Excel, and the client-side implementations of connected experiences. Connected experiences are features of Office applications using services deployed in the Microsoft backend. They may communicate and exchange data with the Microsoft backend during operation. There are non-deactivatable features (Microsoft refers to them as essential connected experiences) and deactivatable features (Microsoft refers to them as non-essential connected experiences) [ms_cexp]. The non-deactivatable features cannot be deactivated by users. An example non-deactivatable feature is Licensing [ms_epriv]. It handles licensing of Office applications, such as verifying the validity of a deployed license. The deactivatable features may be deactivated by users through standard configuration interfaces, such as group policy settings or registry values. An example deactivatable feature is Insert Icons. It enables users to insert in documents icons provided by Microsoft online [ms_nepriv].

Both Office applications and connected experiences produce diagnostic events that may be sent to Microsoft. This work refers to this concept as Office telemetry. Office produces a specific diagnostic event when it performs a given activity, which may be triggered by users. Such activities include, for example, launching the Office application or saving a document. Diagnostic events produced by Office are sent to
Microsoft by telemetry modules. In this work, the term *telemetry module* refers to a software entity that establishes a network connection to an endpoint that is part of the Microsoft backend and sends diagnostic events produced by Office to it. There are Office and Windows telemetry modules. The term *Office telemetry module* refers to a telemetry module distributed with Office. The term *Windows telemetry module* refers to a telemetry module that is not distributed with Office (e.g., it is distributed with Windows).

Microsoft has released a set of privacy settings for Office, one of which enables users to configure the type and amount of diagnostic data that Office may send to the Microsoft backend. When deployed, it is available in the form of a group policy setting at the policy path `User Configuration\Administrative Templates\Microsoft Office 2016\Privacy\Trust Center\Configure the level of client software diagnostic data sent by Office to Microsoft`. It allows users to configure one of the following *diagnostic data levels*:

- **required**: this level configures Office to send to Microsoft the "*minimum data needed to keep Office secure, up-to-date, and performing as expected on the device it's installed*" (cit., from the group policy setting description);
- **optional**: this level configures Office to send to Microsoft "*additional data that helps make product improvements and provides enhanced information to help detect, diagnose, and remediate issues*" (cit., from the group policy setting description);
- **neither**: this level configures Office such that "*no diagnostic data about Office client software running on the user's device is sent to Microsoft*" (cit., from the group policy setting description).

When the policy setting is not configured, the level *optional* is applied. For the sake of simplicity, this work refers to the policy setting *Configure the level of client software diagnostic data sent by Office to Microsoft* as *Office diagnostic level*. Configuring the diagnostic data level required, optional, or neither results in setting the registry value `HKEY_CURRENT_USER\Software\Policies\Microsoft\office\common\clienttelemetry\sendtelemetry` to 1, 2, and 3, respectively. This can be observed by analyzing the content of the `office16.admx` file. This file implements the *Office diagnostic level* setting (see Figure 1).

![Figure 1: Content of office16.admx: Diagnostic data levels](image-url)
1.2 Scope

The objective of this work is:

- to analyze the impact of the required, optional, and neither diagnostic data levels on the output of diagnostic data produced by Office applications and featured connected experiences (see Section 1.1). This work discusses in detail only topics that are directly related to this objective. Other topics are either not discussed, or are discussed to the extent needed for better understanding the content of this work. Such topics include characterizing the network traffic between a telemetry module and the Microsoft backend, or analyzing in detail the way in which Office applications and connected experiences produce diagnostic events;

- to provide and evaluate approaches for partially or fully disabling the output of diagnostic data produced by Office applications and featured connected experiences. This work evaluates such approaches in terms of their complexity of technical feasibility and impact on the operation of Office.

Office telemetry (see Section 1.1) is not to be confused with Office Telemetry Dashboard. Office Telemetry Dashboard is an on-premise tool that collects diagnostic data about Office, primarily intended for organization-internal application compatibility testing [ms_otd]. This data is different than the diagnostic data discussed in this work. The Office Telemetry Dashboard tool is not in the scope of this work.

The observations presented in this work are based on a static code analysis performed using the IDA disassembler and dynamic code analysis performed using the windbg debugger. Debugging symbols for Office are not publicly available.

1.2.1 Technical information

This section provides information on: i) the executable files that are subject of analysis and their execution environment (paragraph ‘Operating system’, ‘Microsoft Office 365’, and ‘Executable files’); and ii) the configuration settings for Office that are subject of analysis (paragraph ‘Configuration settings’, see Section 1.1).

Operating system Microsoft Windows 10 Enterprise long-term servicing channel (LTSC), version 10.0.17763, build 17763, 64-bit, default configuration.

Microsoft Office 365 Microsoft Office 365 Business, version 1904, build 11601.20230 Click-to-Run, 64-bit, licensed, default configuration.

Installed Office applications (with all connected experiences enabled, as per the default configuration of Office):

- Access: %ProgramFiles%\Microsoft Office\root\Office16\MSACCESS.EXE
- Excel: %ProgramFiles%\Microsoft Office\root\Office16\EXCEL.EXE
- OneNote: %ProgramFiles%\Microsoft Office\root\Office16\ONENOTE.EXE
- Outlook: %ProgramFiles%\Microsoft Office\root\Office16\OUTLOOK.EXE
- PowerPoint: %ProgramFiles%\Microsoft Office\root\Office16\POWERPNT.EXE
- Publisher: %ProgramFiles%\Microsoft Office\root\Office16\MSPUB.EXE
- Word: %ProgramFiles%\Microsoft Office\root\Office16\WINWORD.EXE
- Skype for Business: %ProgramFiles%\Microsoft Office\root\Office16\lync.exe

Executable files

%ProgramFiles%\Microsoft Office\root\vfs\ProgramFilesCommonX64\Microsoft Shared\OFFICE16\Mso20win32client.dll: file version: 16.0.11601.20184; file size: 7.028.760 bytes.
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%ProgramFiles%\Microsoft Office\root\Office16\MSOARIANEXT.dll: file version: 16.0.11601.20174; file size: 1.318.944 bytes.

Configuration settings: Administrative Template files (ADMX/ADML) and Office Customization Tool for Office 365 ProPlus, Office 2019, and Office 2016, version 4936.1000.

1.3 Summary

The Windows 10 operating system implements the concept of telemetry. This involves collecting and sending diagnostic data to a backend managed by Microsoft (i.e., the Microsoft backend) for storing and processing. Diagnostic data is a set of diagnostic events that log information on different aspects of the operation of Windows and applications running on it. This includes usage information as well as information relevant for diagnosing issues, such as application crash information. Microsoft Office 365 (i.e., Office) consists of Office applications, such as Word and Excel, and connected experiences. Connected experiences are features of Office applications that may communicate and exchange data with the Microsoft backend during operation. Both Office applications and connected experiences produce diagnostic events that may be sent to Microsoft. Microsoft has released a set of privacy settings for Office, in the form of group policy settings. One of them enables users to configure the type and amount of diagnostic data that Office may send to the Microsoft backend by configuring the diagnostic data level required, optional, or neither. According to the group policy setting description, the diagnostic data level neither configures Office such that “no diagnostic data about Office client software running on the user’s device is sent to Microsoft” (cit., from the group policy setting description).

It is important to emphasize that:

- the diagnostic data level neither configures Office such that only specific diagnostic events are not sent to Microsoft. Other diagnostic events produced by Office applications and featured connected experiences are still sent to Microsoft;
- depending on how Office is used, diagnostic data produced by it may be sent to Microsoft through more than one telemetry module. Telemetry modules are software entities that collect Office diagnostic events, establish a network connection to an endpoint of the Microsoft backend, and send the diagnostic events to it. Office diagnostic data may be sent to Microsoft by telemetry modules distributed with Windows or Office itself.

There is no known central configuration setting that disables all telemetry modules. There is also no such setting that configures Office to stop producing diagnostic events. Fully disabling the output of diagnostic data produced by Office requires the application of a combination of approaches. They involve blocking outgoing data streams at network-level and configuring settings using standard system configuration interfaces, such as group policy settings or the system’s registry. The approaches vary in their efficacy (in terms of amount of disabled diagnostic data output), complexity of technical feasibility, and impact on the operation of Office applications and featured connected experiences. Partially or fully disabling the output of diagnostic data produced by Office limits Microsoft’s ability to diagnose and remediate problems in using Office.
2 Technical Analysis

This section first provides a high-level overview of Office telemetry. It also discusses the impact of the required, optional, and neither diagnostic data levels on the output of diagnostic data produced by Office (Section 2.1 and Section 2.2).

Figure 2 depicts a high-level overview of the architecture of Office telemetry. When an Office application or a featured connected experience is launched, it starts producing diagnostic events. These events may be sent to the Microsoft backend by Windows or Office telemetry modules ('Windows telemetry modules' and 'Office telemetry modules' in Figure 2, see Section 1.1).

Windows telemetry modules Some Windows telemetry modules are the Connected User Experiences and Telemetry service and the (Object Linking and Embedding) OLE32 Extensions for Win32 Windows component.

The Connected User Experiences and Telemetry service: The DiagTrack service, the core building block of Connected User Experiences and Telemetry, receives diagnostic events from the Diagtrack-Listener ETW session (see Section 1.1). An Office application may produce diagnostic events using ETW providers that are associated with Diagtrack-Listener. This means that these events are consumed by Connected User Experiences and Telemetry. Depending on its configuration, Connected User Experiences and Telemetry may send the events to Microsoft.

The section 'ETW Providers: Word and Diagtrack-Listener’ in the Appendix lists the GUIDs of the ETW providers that: i) may be used by Word for producing diagnostic events; and ii) are associated with Diagtrack-Listener when Word runs. We identified the GUIDs of the ETW providers that may be used
by Word for producing diagnostic events with the `logman` utility: `logman query providers -pid [PID]`, where `[PID]` stands for process ID. We identified the GUIDs of the ETW providers associated with Diagtrack-Listener by executing the `Get-EtwTraceProvider -SessionName "Diagtrack-Listener"` PowerShell command. The section ‘ETW Providers: Word and Diagtrack-Listener’ in the Appendix lists the matching GUIDs. They may differ depending on system and Office state and configuration.

Figure 3 depicts the ETW provider with GUID D1318FE0-16B7-4FB-b5F9-BA3CD54CD9CC producing the diagnostic event named `Office.TelemetryEngine.FirstProcessed` (displayed with the Message Analyzer utility). This event is produced by a running Office application (Word) with a process ID (PID) of 7116. The ETW provider is associated with the Diagtrack-Listener ETW session (see section ‘ETW Providers: Word and Diagtrack-Listener’ in the Appendix). The event `Office.TelemetryEngine.FirstProcessed` is collected by Connected User Experiences and Telemetry when the telemetry level Enhanced(Limited) is configured [ms_el].

**Figure 3: The diagnostic event Office.TelemetryEngine.FirstProcessed**

OLE32 Extensions for Win32: When a user inserts an icon provided by Microsoft in a Word document (i.e., when a user uses the Insert Icon connected experience, see Section 1.1), Office uses the Windows OLE technology. This results in the `%SystemRoot%\urlmon.dll` Dynamic Link Library (DLL) library file sending diagnostic events to the `hubblecontent.osi.office.net/contentsvc/api/telemetry/ux?` endpoint of the Microsoft backend. `urlmon.dll` is part of the OLE32 Extensions for Win32 component. Figure 4 shows `urlmon.dll` constructing a POST request directed to `hubblecontent.osi.office.net/contentsvc/api/telemetry/ux?` (label [1]) using the WinINet library (label [2], [ms_wini]). The POST request encapsulates a diagnostic event in JavaScript Object Notation (JSON) format (label [3], displayed with Fiddler [fid]).

**Office telemetry modules** By default, Office uses the telemetry module implemented in the `%ProgramFiles%\Microsoft Office\root\Office16\MSOARIANEXT.dll` DLL library file. This work refers to this telemetry module as Aria (‘Aria’ in Figure 2). `MSOARIANEXT.dll` is loaded in the context of an Office application when launched. Aria is responsible for encapsulating diagnostic events produced by Office into POST requests and sending these requests to Microsoft. We observed that Aria sends diagnostic events to the `self.events.data.microsoft.com/OneCollector/1.0` endpoint (see Figure 2). Office delivers diagnostic events to Aria by invoking functions implemented in `MSOARIANEXT.dll`.

It is important to emphasize that there are multiple criteria based on which only specific diagnostic events produced by Office are actually delivered to Aria and sent to Microsoft. Section 2.2 discusses these criteria. This includes the impact of the required, optional, and neither diagnostic data levels on the output of diagnostic data produced by Office (see Section 1.2). Section 2.1 discusses the main functionalities of Aria.

If the registry value `HKEY_CURRENT_USER\Software\Policies\Microsoft\office\common\clienttelemetry\EnableWriteTelemetryEventsToNexus` is set to 1, Office applications do not use Aria, but the telemetry module referred to as Nexus in this work. We observed that this module sends diagnostic events to the `nexus.officeapps.live.com/nexus/upload` endpoint of the Microsoft backend (see Figure 2). A detailed analysis of Nexus is out of scope.
2.1 Functionalities of Aria

This section provides a high-level overview of the functionalities of the Aria telemetry module. The focus is on the functionalities that are relevant to the objectives of this work. Since debugging symbols are not available (see Section 1.2), this section refers to mentioned functions and variables using labels we assigned. Table 1 lists labels assigned to function and variables located at specific offsets from the base addresses of executables (i.e., images). In Table 1, in section 'Functions' and 'Variables': the column 'Label'/'Label [data type]' lists function and variable labels, and the type of the data stored in variables; the column 'Offset', sub-column 'Image', lists image names; the column 'Offset', sub-column 'Value', lists offsets from the base addresses of images.

By default, Office uses the Aria Office telemetry module for sending diagnostic events to the Microsoft backend. Office applications load the MSOARIANEXT.dll library file when launched, which is where Aria is implemented. Office then delivers diagnostic events to Aria by invoking functions implemented in MSOARIANEXT.dll. Aria stores these events, encapsulates them in POST requests, and sends them to Microsoft.
In order to observe the functionalities of Aria, we patched the value of the `aria_logVerbosity` variable to 0x4 when MSOARIANEXT.dll is loaded (see Table 1 and Figure 5). The value of this variable controls the verbosity level of the log data produced by Aria. The value 0x4 configures the highest verbosity level. Aria log data provides information on the inner working principles of Aria. It can be displayed by a debugger attached to an Office application that has loaded MSOARIANEXT.dll (see Figure 5).

Once MSOARIANEXT.dll is loaded, Office starts delivering diagnostic events to Aria. The `aria_diagnosticEventLogger` function implemented in MSOARIANEXT.dll (see Table 1) is executed for each event delivered to Aria. Among other things, the execution of `aria_diagnosticEventLogger` results in storing the delivered event in an in-memory database that Aria manages (‘in-memory event storage’ in Figure 2). Figure 6 depicts Aria log data that provides information on the storage of the diagnostic event named `Office.Performance.Boot`.

![Figure 5: Patching aria_logVerbosity and displaying Aria log data](image)

Table 1: Function and variable labels (1)

<table>
<thead>
<tr>
<th>Functions</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Label</td>
<td>Image</td>
</tr>
<tr>
<td>aria_diagnosticEventLogger</td>
<td>MSOARIANEXT.dll</td>
</tr>
<tr>
<td>aria_offlineStorageTimeout</td>
<td>MSOARIANEXT.dll</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Label [data type]</td>
<td>Image</td>
</tr>
<tr>
<td>aria_logVerbosity</td>
<td>[byte]</td>
</tr>
</tbody>
</table>

![Figure 6: Depicts Aria log data that provides information on the storage of the diagnostic event named 'Office.Performance.Boot'](image)
Figure 6: Storage of a diagnostic event delivered to Aria

Figure 7: Aria constructing a POST request that encapsulates diagnostic events
If Internet connection is available, Aria schedules the sending of the diagnostic events stored in its in-memory database to the self.events.data.microsoft.com/OneCollector/1.0 endpoint of the Microsoft backend. To this end, Aria executes functions of the WinInet library, such as HttpOpenRequestA, HttpAddRequestHeadersA, and HttpSendRequestW [ms_wini]. WinInet constructs POST requests such that each request encapsulates multiple diagnostic events. HttpSendRequestW issues POST requests to self.events.data.microsoft.com/OneCollector/1.0 through an encrypted communication channel.

The events encapsulated in POST requests are serialized with the Bond Compact Binary protocol [ms_bond]. This protocol achieves high payload compactness. It is therefore suitable for scenarios where data has to be frequently sent over a network connection and the caused network overhead due to data transfer needs to be kept at minimum. Figure 7 depicts Aria constructing a POST request in order to send diagnostic events to self.events.data.microsoft.com/OneCollector/1.0 (label [1]). The first event stored as part of this request is named Office.System.SystemHealthErrorsWithTag [ms_req]. Figure 7 also depicts the POST request as observed with Fiddler (label [2]). Fiddler acts as the man-in-the-middle between the Windows 10 instance where an Office application runs and the Microsoft backend.

When a user closes an Office application, if Internet connection is available, Aria sends to self.events.data.microsoft.com/OneCollector/1.0 the diagnostic events that have not been already sent. If Internet connection is not available, Aria stores these diagnostic events in persistent storage (‘on-disk event storage’ in Figure 2). This storage is an SQLite database. It is stored in the \%HOMEPATH\\AppData\Local\Microsoft\Office\OTele\ folder, in a database (.db) file.1 Aria stores diagnostic events in persistent storage during a timeout interval by invoking the aria_offlineStorageTimeout function (see Table 1). Windows terminates the Office application when the timeout expires.

2.2 Delivery of diagnostic events to Aria

This section discusses how diagnostic events produced by Office are delivered to Aria. The focus is on the criteria based on which only specific diagnostic events are delivered to Aria. Since debugging symbols are not available (see Section 1.2), this section refers to mentioned functions and variables using labels we assigned (see Table 2). Functions are located at specific offsets from the base addresses of images. Variables are located at offsets from the value of a parameter passed to a function, from a variable value, or from the base address of an image. As per Microsoft’s function calling convention, the first parameter of a function receiving integers as parameters is stored in the rcx register, whereas the second in the rdx register [ms_cc]. In Table 2:

- in section ‘Functions’: the column ‘Label’ lists function labels; the column ‘Offset’, sub-column ‘Image’, lists image names; the column ‘Offset’, sub-column ‘Value’, lists offsets from the base addresses of images;
- in section ‘Variables’: the column ‘Label [data type]’ lists variable labels and the type of the data stored in variables; the column ‘Offset’, sub-column ‘Image/Function/Variable’, lists image names, function labels, or variable labels; the column ‘Offset’, sub-column ‘Parameter’, lists function parameters (where applicable); the column ‘Offset’, sub-column ‘Value’, lists offsets from the base addresses of images, from function parameter values, or from variable values.

1 msaccess.exe.db for Access; excel.exe.db for Excel; onenote.exe.db for OneNote; outlook.exe.db for Outlook; powerpnt.exe.db for PowerPoint; mspub.exe.db for Publisher; winword.exe.db for Word; lync.exe.db for Skype for Business.
## Functions

<table>
<thead>
<tr>
<th>Label</th>
<th>Image/Function/Variable</th>
<th>Offset</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>mso20_eventCheck</td>
<td>Mso20win32client.dll</td>
<td>0x3D76C</td>
<td></td>
</tr>
<tr>
<td>mso20_transportToAria2</td>
<td>Mso20win32client.dll</td>
<td>0x331CC</td>
<td></td>
</tr>
<tr>
<td>mso20_eventDLevelCheck</td>
<td>Mso20win32client.dll</td>
<td>0x1C52F4</td>
<td></td>
</tr>
<tr>
<td>mso20_transportToAria1</td>
<td>Mso20win32client.dll</td>
<td>0x1523F0</td>
<td></td>
</tr>
<tr>
<td>mso20_transportToAria</td>
<td>Mso20win32client.dll</td>
<td>0x152610</td>
<td></td>
</tr>
</tbody>
</table>

## Variables

<table>
<thead>
<tr>
<th>Label [data type]</th>
<th>Image/Function/Variable</th>
<th>Offset</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>event_activation [byte]</td>
<td>mso20_eventCheck</td>
<td>rdx</td>
<td>0x10</td>
<td></td>
</tr>
<tr>
<td>event_diagnosticLevel [byte]</td>
<td>mso20_eventDLevelCheck</td>
<td>rcx</td>
<td>0x6</td>
<td></td>
</tr>
<tr>
<td>event_criticality [byte]</td>
<td>mso20_transportToAria1</td>
<td>rdx</td>
<td>0x71</td>
<td></td>
</tr>
<tr>
<td>setSettings [pointer]</td>
<td>mso20win32client.dll</td>
<td>/</td>
<td>0x633200</td>
<td></td>
</tr>
<tr>
<td>setTelemetryLevel [byte]</td>
<td>setSettings</td>
<td>/</td>
<td>0x162</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Function and variable labels (2)

Figure 8 depicts the functions executed in close proximity to the aria_diagnosticEventLogger function, resulting in its execution (see Section 2.1). These functions are implemented in the Mso20win32client.dll DLL library file (see Section 1.2.1). Among other things, they evaluate properties of the diagnostic events directed to Aria. These properties serve as event descriptors and their values can be accessed as variables in the context of specific functions. The variables in Table 2 with names starting with event_ store values of event properties. The event properties mentioned in this section are:

- **activation policy:** If set to 0x2, this property marks the event as deactivated. The value of this event property is stored in the event_activation variable (see Table 2);

- **diagnostic level:** This property is the diagnostic data level associated with the event (see Section 1.2). The value of this event property is stored in the event_diagnosticLevel variable (see Table 2). Possible values of diagnostic level are:
  - 0xA: marks the diagnostic data level required (internally named B);
  - 0x64: marks the diagnostic data level optional (internally named F);
  - 0x6E: marks the diagnostic data level internally named N;
  - 0x78: marks the diagnostic data level internally named A;

- **criticality:** This property is the level of event criticality. The value of this event property is stored in the event_criticality variable (see Table 2). Possible values of criticality are:

2 We extracted the possible values of diagnostic level and their internal names from the context of the function implemented at offset 0x394520 from the base address of Mso20win32client.dll.
• 0x1: marks a non-critical event;
• 0xBF, 0xC0, 0xC1, and 0xC2: mark critical events of different criticalities (with internal names): 0xBF - CriticalBusinessImpact, 0xC0 - CriticalCensus, 0xC1 - CriticalExperimentation, and 0xC2 - CriticalUsage.³

The criteria based on which only specific diagnostic events are delivered to Aria take into account the values of these event properties. This section discusses only the activation policy, diagnostic level, and criticality event properties, since they are relevant to the objective of this work (see Section 1.2). There are other properties that are not discussed in this section.

For each diagnostic event directed to Aria, first the mso20_eventCheck function is invoked. This function evaluates different aspects of the event, such as whether the name of the event is valid or too long. It also evaluates the value of the activation policy event property. If an evaluation in mso20_eventCheck fails, the function returns a zero value and the function execution sequence depicted in Figure 8 is interrupted. The diagnostic event will not be delivered to Aria. mso20_eventCheck returns zero if the diagnostic event is marked as deactivated, that is, if the event property activation policy (or equivalently, the event_activation variable) is set to 0x2. Therefore, deactivated events are not delivered to Aria (see [event_activation] in Figure 8).

If mso20_eventCheck returns a non-zero value, the function mso20_transportToAria2 is executed. This function invokes the function mso20_eventDLevelCheck. mso20_eventDLevelCheck evaluates the diagnostic level property of the event (or equivalently, the

³ We extracted the possible values of criticality and their internal names from the context of the function implemented at offset 0xB0660 from the base address of Mso20win32client.dll and by matching events of different criticalities sent to Microsoft with events specified in a rule file. Rule files are discussed later in this section.
event_diagnosticLevel variable) and returns 0 or 1. If it returns 0, the function execution sequence depicted in Figure 8 is interrupted. The diagnostic event will not be delivered to Aria.

Figure 9 depicts a pseudo-code of the implementation of mso20_eventDLevelCheck. This function decides whether a diagnostic event will be delivered to Aria by taking the diagnostic data levels required, optional, and neither into account. The setTelemetryLevel variable (see Table 2) stores the value of the registry value HKEY_CURRENT_USER\Software\Policies\Microsoft\office\common\clienttelemetry\sendtelemetry, which users set by configuring the Office diagnostic level policy setting. If event_diagnosticLevel is set to:

- 0x78 (i.e., A): mso20_eventDLevelCheck returns 1 and the diagnostic event is directed further to Aria;
- 0xA (i.e., required, or B): mso20_eventDLevelCheck returns 1 if the user has configured the policy setting Office diagnostic level to required (the registry value sendtelemetry is 1) or Optional (the registry value sendtelemetry is 2). The diagnostic event is directed further to Aria (see ‘[event_diagnosticLevel]’ in Figure 8);
- 0x64 (i.e., optional, or F): mso20_eventDLevelCheck returns 1 if the user has configured the policy setting Office diagnostic level to optional (the registry value sendtelemetry is 2). The diagnostic event is directed further to Aria (see ‘[event_diagnosticLevel]’ in Figure 8);
- 0x6E (i.e., N): mso20_eventDLevelCheck returns 1 if the value stored at offset 0x188 of the setSettings variable is set to 1. The diagnostic event is directed further to Aria. The role of the value stored at offset 0x188 of setSettings is not in the scope of this work.

In summary, a configured diagnostic data level required, optional, or neither is a criterion based on which a specific diagnostic event is delivered to Aria and sent to Microsoft only if the event’s property diagnostic level is 0xA or 0x64.

```c
mso20_eventDLevelCheck()
{
    if (event_diagnosticLevel == 0x78) return 1;
    if (event_diagnosticLevel == 0xA)
    {
        if (setTelemetryLevel != 3) return 1;
        else return 0;
    }
    if (event_diagnosticLevel == 0x64)
    {
        if (setTelemetryLevel == 2) return 1;
        else return 0;
    }
    if (event_diagnosticLevel == 0x6E)
    {
        if (setSettings[0x188] == 1) return 1;
        else return 0;
    }
}
```

Figure 9: Pseudo-code of the implementation of mso20_eventDLevelCheck

If mso20_eventDLevelCheck returns 1, the function mso20_transportToAria1 is executed. Among other things, this function evaluates the event property criticality (or equivalently, the event_criticality variable). The value of this event property is relevant if the stream of diagnostic events is sampled. In such a case, only some diagnostic events are directed further to Aria and eventually
sent to Microsoft. Which events are directed further to Aria depends on the value of the criticality event property of each event. If the stream is sampled, `mso20_transportToAria1` delivers to Aria only the diagnostic events that are marked as critical – events with the criticality property set to `CriticalBusinessImpact`, `CriticalCensus`, `CriticalExperimentation`, or `CriticalUsage` (see ‘[event_criticality]’ in Figure 8). To deliver a diagnostic event to Aria, `mso20_transportToAria1` invokes the `mso20_transportToAria` function. This function invokes the `aria_diagnosticEventLogger` function, at which point the diagnostic event is eventually sent to Microsoft (see Section 2.1).

The concept of event criticality is best observed in the context of telemetry rules. Telemetry rules are specified in Extensible Markup Language (XML) format and are stored in rule files (rule file’ in Figure 2). Rule files are stored in the `%HOMEPATH%\AppData\Local\Microsoft\Office\16.0\folder, such that each Office application has a dedicated rule file. An Office application may request a rule file from the `nexusrules.officeapps.live.com/nexus/rules` endpoint of the Microsoft backend (see Figure 10, label [1] marks a request for a rule file, label [2] marks a response from `nexusrules.officeapps.live.com`, displayed with Fiddler).

Each rule stored in a rule file may contain sub-rules and is uniquely identified by a rule ID. Among other things, telemetry rules specify critical diagnostic events and event data sources. Some sources of diagnostic events are: ETW providers, uniquely identified by their GUIDs, and Unified Logging System (ULS) tags, uniquely identified by ULS tag IDs (e.g., `avuo1`, `bhyud`). ULS is an application logging mechanism. Each diagnostic event specified by a rule is associated with an event name and event criticality, also known as sampling policy. An Office application parses its rule file when started and matches over its lifetime.
produced diagnostic events to rules. Matching events are directed to Aria. Therefore, rules may be understood as remotely deployed generators of diagnostic events dynamically configuring the diagnostic event collection process of Office (see 'configuration data flow’ in Figure 2).

Figure 11 depicts portions of telemetry rules for Word. The rules specify events associated with the different event criticalities - CriticalBusinessImpact, CriticalCensus, CriticalExperimentation, and CriticalUsage. In Figure 11: the XML tag R specifies a rule; the XML attribute EN specifies an event name; the XML attribute SP specifies sampling policy (i.e., event criticality); the XML tag Etw specifies an ETW provider as an event data source; and the XML tag UTS specifies an ULS event data source.

![Figure 11: Portions of telemetry rules](image)

In addition to event names, criticalities, and event data sources, telemetry rules typically specify other event descriptors and operations over data, such as logical comparisons. A detailed analysis of telemetry rules is out of scope. To facilitate further research, the section 'Telemetry rules: XML tags/attributes and interpretations’ in the Appendix non-exhaustively lists XML tags and attributes (column 'XML tag/attribute'), and their associated Office-internal interpretations (column 'Interpretations'). We extracted these interpretations as string literals from Mso20win32client.dll. Depending on its placement in a rule file, a single entry in the column 'XML tags/attribute' may be an XML tag or an attribute and may have more than one interpretation (comma-separated in column 'Interpretations').

Table 3 shows the number of diagnostic events directed and delivered to Aria, in the scenario where we conducted the following activities in Word: i) launching Word; ii) creating a new document; iii) writing the sentence “Test.”; iv) saving the document using the 'Save as' feature; and v) closing Word. Under an event directed to Aria, we understand a diagnostic event reaching the mso20_transportToAria1 function in Mso20win32client.dll. Under an event delivered to Aria, we understand a diagnostic event reaching the mso20_transportToAria function in Mso20win32client.dll and subsequently the aria_diagnosticEventLogger function in MSOARIANEXT.dll (see Figure 8).

For each diagnostic data level configured using the policy setting Office diagnostic level, Table 3 categorizes diagnostic events with respect to their criticality (column ‘Event criticality’) and diagnostic level (table section ‘Event diagnostic level’). Section ‘Total number of events delivered to Aria’ of Table 3 shows the number of diagnostic events that are delivered to Aria and eventually sent to Microsoft (see Section 2.1).
Table 3 effectively shows the impact of configuring the policy setting **Office diagnostic level** on the output of diagnostic data produced by Office applications and featured connected experiences.

When the diagnostic data level *neither* is configured, events of the diagnostic levels 0xA and 0x64 are not directed to Aria. When the diagnostic data level *required* is configured, only events of the diagnostic level 0x64 are not directed to Aria (see Figure 8). When the diagnostic data level *optional* is configured, events of all diagnostic levels are directed to Aria, including a high number of events of the diagnostic level 0x64.

Since the stream of diagnostic events is sampled, only the diagnostic events marked as critical (i.e., with the **criticality event property** set to **CriticalBusinessImpact**, **CriticalCensus**, **CriticalExperimentation**, or **CriticalUsage**) are delivered to Aria and eventually sent to Microsoft. This shows the impact of diagnostic event criticality on the output of diagnostic data produced by Office applications and featured connected experiences.

<table>
<thead>
<tr>
<th>Event criticality</th>
<th>Diagnostic data level</th>
<th>Event diagnostic level: 0xA</th>
<th>Event diagnostic level: 0x78</th>
<th>Event diagnostic level: 0x6E</th>
<th>Event diagnostic level: 0x64</th>
<th>Total number of events delivered to Aria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>neither</td>
<td>required</td>
<td>optional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>Non-critical</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>11</td>
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<td>21</td>
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<tr>
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<td>0</td>
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<td>0</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Number of diagnostic events directed and delivered to Aria [the Word Office application with all connected experiences enabled, as per the default configuration of Office – see Section 1.2.1]
3 Disabling the output of diagnostic data

This section discusses different approaches for partially or fully disabling the output of diagnostic data produced by Office. It evaluates the approaches in terms of their complexity of technical feasibility and impact on the operation of Office. The approaches can be applied at network- (Section 3.1), registry- (Section 3.2), or group policy-level (Section 3.3). Although the approaches focus on diagnostic data, due to technical reasons, some of them involve disabling the output of non-diagnostic data required for non-essential connected experiences to function (see Section 1.1). The approaches discussed in this section do not disable the output of non-diagnostic data required for Office applications and non-deactivatable features, such as Licensing, to properly function.

This section focuses on approaches that can be applied using standard configuration interfaces, such as the system’s registry or group policy settings. Other approaches, although technically feasible, are not discussed in this section. For example, the output of diagnostic data from the Aria telemetry module may be disabled by setting the second parameter of the mso20_eventCheck function (i.e., the event_activation variable) to 0x2 while an Office application runs. This configures the activation policy event property such that each diagnostic event directed to Aria is marked as deactivated (see Section 2.2).

The Connected User Experiences and Telemetry service may collect diagnostic data produced by Office and send it to Microsoft (see Section 2). [ERNW_WP4.1] discusses approaches on disabling the output of diagnostic data from this service. This telemetry module is not in the scope of this section.

3.1 Network

This approach involves blocking using a firewall outgoing diagnostic data streams from a Windows instance to endpoints of the Microsoft backend. This includes the endpoints to which Office and Windows telemetry modules send diagnostic events (see Section 1.1). In the context of this work, we observed that the Aria and Nexus Office telemetry modules send diagnostic events to self.events.data.microsoft.com/OneCollector/1.0 and nexus.officeapps.live.com/nexus/upload. We also observed that OLE32 Extensions for Win32 sends diagnostic events to hubblecontent.osi.office.net/contentsvc/api/telemetry/. [ERNW_WP4.1] provides information on the endpoints to which the Connected User Experiences and Telemetry service sends diagnostic events.

If applied to known endpoints, this approach is easily technically feasible - it is implemented by configuring firewall rules. However, its sustainability and efficacy, in terms of amount of disabled diagnostic data output, are challenged by the following factors:

• software updates and re-configuration: The endpoints of the Microsoft backend to which telemetry modules send diagnostic data may change over time, for example, due to software updates re-configuring the modules. This challenges the sustainability of this approach;

• user activities: Office produces a specific diagnostic event when it performs a given activity, often triggered by users. Diagnostic events are delivered to telemetry modules, after which they send the events to endpoints of the Microsoft backend. For example, Aria sends to Microsoft diagnostic events produced when users perform a variety of activities, such as launching an Office application or saving a document (see Section 2.1). OLE32Extensions for Win32 handles more specific diagnostic events. For example, it sends diagnostic events to Microsoft when a user uses the Insert Icon connected experience (see Section 2). To what specific endpoints diagnostic events produced by Office may be sent largely depends on performed user activities. To achieve full approach efficacy, these activities should be known before configuring firewall rules.
Disabling the output of diagnostic data

The sustainable and effective implementation of this approach involves performing the following steps:

1) identifying all activities that users may perform in the context of Office applications and featured connected experiences ('identify user activities' in Figure 12);

2) while performing the activities, observing the endpoints of the Microsoft backend to which diagnostic events are sent. This can be done by using a network sniffer acting as the man-in-the-middle between the Windows instance in which Office runs and the Microsoft backend (e.g., Fiddler, 'perform activities & observe endpoints' in Figure 12);

3) configuring firewall rules that block outgoing diagnostic data streams from the Windows instance to the observed endpoints ('configure firewall rules' in Figure 12). If an endpoint is in the form of a hostname and an Uniform Resource Locator (URL) path (e.g., self.events.data.microsoft.com/OneCollector/1.0), it is important that configured firewall rules specify the endpoint by its hostname and the full URL path. This is because:

   • there may be multiple IP addresses associated with a single hostname. For example, self.events.data.microsoft.com is associated with multiple IP addresses. This makes blocking outgoing data streams only to a specific IP address, or a hostname, inefficient;

   • some hostnames specify endpoints that not only collect diagnostic events, but also deliver content to Office. For example, in addition to collecting diagnostic events at the URL path /contentssvc/api/telemetry/, hubblecontent.osi.office.net delivers on request icon data when the Insert Icon connected experience is used. Blocking outgoing data streams only to the hostname hubblecontent.osi.office.net, without specifying an URL path, impacts the operation of the Insert Icon connected experience.

Windows Defender Firewall, the Windows built-in firewall, does not support blocking outgoing data streams to endpoints specified by hostnames and URL paths. Therefore, the implementation of this approach requires a third-party firewall solution that supports such blocking. This feature is typical for enterprise network filtering solutions.

An alternative, technically simpler, approach to blocking outgoing streams to specific endpoints is to block all outgoing data streams from an Office application. However, this may render Office applications and featured connected experiences unusable, disabling both non-deactivatable and deactivatable features. This includes verifying or changing a license [ms_lic], inserting icons, and deploying new, or using existing, application extensions (i.e., add-ins).

Given non-changing user activities, step 2) and 3) should be regularly repeated so that the implementation of the approach is sustainable over long-term periods.
3.2 Registry

Setting the registry value HKEY_CURRENT_USER\Software\Policies\Microsoft\office\common\clienttelemetry\DisableTelemetry to 1 disables the Aria and Nexus Office telemetry modules (see Section 2). For example, if DisableTelemetry is set to 1, Office applications do not load the MSOARIANEXT.dll library file, which implements Aria (see Section 2.1). The registry value DisableTelemetry cannot be configured through the privacy policy settings for Office that Microsoft has released (see Section 1.1). It has to be configured by editing the system's registry. DisableTelemetry is not present in the registry by default. Its default value, if a user does not explicitly create and configure DisableTelemetry, is 0. It is important to emphasize that the DisableTelemetry registry value is not officially documented by Microsoft. Therefore, its impact on the output of Office diagnostic data may be subject to change without public notice.

The advantage of this approach is its simple technical feasibility– it is implemented by configuring a registry value. It is also effective in disabling the output of diagnostic data from the Aria and Nexus telemetry modules. It also does not impact the operation of Office applications and featured connected experiences. However, it disables the output of diagnostic data only from the Aria and Nexus Office telemetry modules. It does not disable, for example, the output of diagnostic data produced by connected experiences, sent to Microsoft by Windows telemetry modules (see Section 2). For example, when DisableTelemetry is set to 1, OLE32 Extensions for Win32 still sends diagnostic events to hubblecontent.osi.office.net/contentsvc/api/telemetry when a user uses the Insert Icon connected experience in Word.

In addition to DisableTelemetry, there are other registry values that are relevant for disabling the output of diagnostic data produced by Office. They can be configured through group policy settings and are therefore discussed in Section 3.3.

3.3 Group policy

This approach involves configuring group policy settings. Configuring the policy setting:

- **at the policy path** User Configuration\Administrative Templates\Microsoft Office 2016\Privacy\Trust Center\Configure the level of client software diagnostic data sent by Office to Microsoft to Enabled;

- and Type of diagnostic data to Neither partially disables the output of diagnostic data from Aria such that only events of diagnostic level 0x78 and 0x6E are sent to Microsoft (see Table 3);

- **at the policy path** User Configuration\Administrative Templates\Microsoft Office 2016\Privacy\Trust Center\Allow the use of connected experiences in Office to Disabled disables all non-essential connected experiences and therefore disables the output of diagnostic data produced by them. However, the disabled connected experiences are then not available to users. This does not include non-deactivatable features, such as Licensing. Users may enable or disable a certain group of non-essential connected experiences by configuring the policy settings at the policy paths [ms_pc]:

  - User Configuration\Administrative Templates\Microsoft Office 2016\Privacy\Trust Center\Allow the use of connected experiences that analyze content;

  - User Configuration\Administrative Templates\Microsoft Office 2016\Privacy\Trust Center\Allow the use of connected experiences that download online content; and
Disabling the output of diagnostic data

- User Configuration\Administrative Templates\Microsoft Office 2016\Privacy\Trust Center\Allow the use of additional optional connected experiences in Office.

Configuring the policy settings above results in the setting of registry values:

- Allow the use of connected experiences in Office sets the registry value HKEY_CURRENT_USER\Software\Policies\Microsoft\office\16.0\common\privacy\disconnectedstate (1 - Enabled; 2 - Disabled);
- Allow the use of connected experiences that analyze content sets the registry value HKEY_CURRENT_USER\Software\Policies\Microsoft\office\16.0\common\privacy\usercontentdisabled (1 - Enabled; 2 - Disabled);
- Allow the use of connected experiences that download online content sets the registry value HKEY_CURRENT_USER\Software\Policies\Microsoft\office\16.0\common\privacy\downloadcontentdisabled (1 - Enabled; 2 - Disabled);
- Allow the use of additional optional connected experiences in Office sets the registry value HKEY_CURRENT_USER\Software\Policies\Microsoft\office\16.0\common\privacy\controllerconnectedservicesenabled (1 - Enabled; 2 - Disabled).

The advantage of this approach is its simple technical feasibility – it is implemented by configuring policy settings. It is also effective in disabling the output of diagnostic data produced by non-essential connected experiences and partially disabling this output from the Aria telemetry module. However, non-essential connected experiences are not available to users. In addition, the output of diagnostic data from Aria is not fully, but only partially, disabled.

### 3.4 Summary

The approaches presented in Section 3.1, Section 3.2, and Section 3.3 vary in their efficacy (in terms of amount of disabled diagnostic data output), complexity of technical feasibility, and impact on the operation of Office applications and featured connected experiences. With the goal to maximize the amount of disabled diagnostic data output with a minimum technical complexity, users may disable the Aria and Nexus telemetry modules as well as all non-essential connected experiences by configuring registry values.

The section ‘Disabling the output of diagnostic data: .reg file’ in the Appendix presents the content of a Registration Entries (.reg) file. When applied, it disables the Aria and Nexus Office telemetry modules by setting the registry value DisableTelemetry to 1 (see Section 3.2). It also disables all non-essential connected experiences by setting the registry values controllerconnectedservicesenabled, downloadcontentdisabled, andusercontentdisabled to 2 (see Section 3.3). Users may modify the values of controllerconnectedservicesenabled, downloadcontentdisabled, andusercontentdisabled in the .reg file to enable only specific groups of connected experiences (see Section 3.3). In addition, the file sets the registry values HKEY_CURRENT_USER\Software\Policies\Microsoft\office\16.0\common\qmenable and HKEY_CURRENT_USER\Software\Policies\Microsoft\office\16.0\common\sendcustomerdata to 0. This is equivalent to configuring the policy settings User Configuration\Administrative Templates\Microsoft Office 2016\Privacy\Trust Center\Enable Customer Experience Improvement Program and User Configuration\Administrative Templates\Microsoft Office 2016\Privacy\Trust Center\Send personal information to Disabled.  

5 The CIS Microsoft Office 2016 Benchmark ([cis_of], Section 2.24.1) recommends configuring these policy settings to Disabled. The impact of the settings on the output of diagnostic data produced by Office is not in the scope of this work (see Section 1.2).
In addition to disabling Aria and Nexus as well as all non-essential connected experiences, users may block any remaining outgoing streams of diagnostic data at network-level (see Section 3.1). Users may also disable the output of Office diagnostic data from Connected User Experiences and Telemetry (see Section 2, [ERNW_WP4.1]). It is important to note that partially or fully disabling the output of diagnostic data produced by Office limits Microsoft’s ability to diagnose and remediate problems in using Office [ms_req].
## Appendix

### ETW Providers: Word and Diagtrack-Listener

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<tr>
<th>ETW provider GUIDs (total number: 52)</th>
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Telemetry rules: XML tags/attributes and interpretations

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<th>Interpretations</th>
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<td>sources, source, stop after</td>
</tr>
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<td>rule source, resets, right, regex</td>
</tr>
<tr>
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<td>timer</td>
</tr>
<tr>
<td>T</td>
<td>triggers, token, out type</td>
</tr>
<tr>
<td>C</td>
<td>column, count</td>
</tr>
<tr>
<td>G</td>
<td>group, provider ID, guid</td>
</tr>
<tr>
<td>F</td>
<td>file, filter, float</td>
</tr>
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<td>ATT</td>
<td>Aria tenant token</td>
</tr>
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<td>TR</td>
<td>this rule</td>
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<td>A</td>
<td>app event, aggregator</td>
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<td>timeout</td>
</tr>
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<td>ID</td>
<td>rule ID</td>
</tr>
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<td>threshold</td>
</tr>
<tr>
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<td>sequence</td>
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<td>string regex</td>
</tr>
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<td>ULS category severity source</td>
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<td>ULS all categories source</td>
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<td>union source</td>
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Disabling the output of diagnostic data: .reg file

Windows Registry Editor Version 5.00

[HKEY_CURRENT_USER\Software\Policies\Microsoft\office\common\clienttelemetry]
"DisableTelemetry"=dword:00000001

[HKEY_CURRENT_USER\Software\Policies\Microsoft\office\16.0\common]
"sendcustomerdata"=dword:00000000
"qmenable"=dword:00000000

[HKEY_CURRENT_USER\Software\Policies\Microsoft\office\16.0\common\privacy]
"usercontentdisabled"=dword:00000002
"downloadcontentdisabled"=dword:00000002
"controllerconnectedservicesenabled"=dword:00000002
Reference Documentation

ms_etw  

ms_eapi  

ERNW_WP4  
ERNW GmbH: SiSyPHuS Win10 (Studie zu Systemaufbau, Protokollierung, Härtung und Sicherheitsfunktionen in Windows 10): Work Package 4

ms_cexp  

ms_epriv  

ms_nepriv  

ms_ostd  

ms_el  

ms_wini  

fid  

ms_bond  

ms_req  

ms_cc  

ERNW_WP4.1  
ERNW GmbH: SiSyPHuS Win10 (Studie zu Systemaufbau, Protokollierung, Härtung und Sicherheitsfunktionen in Windows 10): Work Package 4.1

ms_lic  

ms_pc  

cis_of  
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