

Part 2: LockBit 2.0 ransomware bugs and database recovery attempts

By Danielle_Veluz

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{"__ref": "ModerationData:moderation_data:3254421"}, "teaser": ""
```

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Before outlining our decryptor and the details of the algorithm alluded to earlier, we must point out yet another subtlety that must be addressed. Due to the unpredictable behavior the encryptor is capable of we are facing further issues, outside of the encryption procedure itself, of potentially irrecoverable corruption. The best way to see this is to have some semblance of the underlying structures involved for a *.ndf* file, which is the format of the database files that we had to work with. The understanding of this structure, at least the essential parts relevant to us, serves as the basis for our recovery algorithm.

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For our purposes, it suffices to understand that for every 0x2000 bytes, we have what are called *pages*. Each page begins with a *header* that is 0x60 bytes in size. Pages can also be classified as empty; 0x2000 bytes full of 0's.

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The header contains valuable metadata that we can leverage to identify areas of corruption. Upon careful examination and side-by-side comparison of all the *.ndf* files that we had to work with, we were able to uncover three relevant properties in the header that would serve as the cornerstone of our recovery algorithm.

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Figure 15. Illustration of all three properties as shown in a hex editor

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The *PageType* field identifies the type of that individual page, which from our understanding can either be a 1 (an occupied page) or a 0 (unoccupied/empty page). The *PageIndex* property identifies the current page and its location within the database file.

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So, "Page 0" would be at "index 0"; "Page 1" would be at "index 1", and so on. It is a way to get to individual pages inside the *.ndf* file. And speaking of the database file itself, what follows the *PageIndex* is yet another unique value that serves to identify the entire *.ndf* file as a whole. In the above case this is indicated by the value "4", but other database files had "3" as a value here instead. What we care about, which is being able to identify the integrity of each individual page that we come across, is that this is a value that we know must be constant throughout each page for each database file we are processing.

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From having a sufficient understanding of the page header, we can construct an algorithm to verify the integrity of each individual page, which in turn allows us to also identify any potential corruption to any of the pages. We can iterate from the start of the file at 0x2000 (page sized) increments and inspect the validity of each header. Wherever we don't have a valid header, we at least know that something is going on at that location which we can investigate further as needed.

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For example, if we wanted to verify that a specific page is valid, we ascertain that the first byte is either a 1 or a 0, and if it is a 1, we go to the 0x20 offset from the start of the header, pull out the 4-byte value there, and calculate whether the *PageIndex* value matches the offset to the start of the page header. We also further validate that the *database identifier* is consistent throughout.

\n\n

Figure 16. Calculating the PageIndex value

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If none of the above conditions are satisfied, then we are looking at corrupted data and we can begin to programmatically identify all these areas. In our case, these were almost exclusively the unintended encrypted regions we outlined earlier.

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If the above conditions are indeed satisfied, we know that we have a valid page at its correct location, so we can note that as well.

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Where the conditions are *half* satisfied is where it gets interesting i.e., we pass the *PageType* and *Database Identifier* check but the *PageIndex* value doesn't match the offset to the start of the page header. We classify these as a **misaligned header** because the *PageIndex* value is pointing to the location of where this header is *supposed* to be:

\n\n

Figure 17. Identifying a misaligned header (off by 0x1000 bytes)

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Also, whenever we hit a zero page (*PageType* == 0), we can safely ignore and continue.

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In the sections described above, we discussed the commonality that all of these database files share: their file format. We outlined the characteristics of an algorithm that can validate the integrity of these database files and categorized four types of classifications by leveraging our understanding of how a *.ndf* database file is supposed to be structured. This, in theory, should be able to deal with all intended and *unintended* corruption the encryptor and decryptor are known to impose.

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Now it's time to put this theory and understanding into practice and build upon this algorithm to achieve our ultimate goal: the successful restoration of all encrypted database files.

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With the stage now set given that all known underlying issues have been exposed, we approached the problem in the following manner.

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We come back to our homemade decryptor now. The details of how our homemade decryptor works under the hood are not as relevant as understanding how we're going to leverage it. More important is being able to identify all the encrypted regions throughout the file and not letting the modified LockBit 2.0 decryptor loose on it to further destroy it.

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But the primary structure of our decryptor is to identify, decrypt, and extract the necessary initialization vector and AES key for the encrypted file, and then utilize this information to carry out the AES decryption through the [mbedtls](#) library, which is exactly the same 3rd party library that the Lockbit 2.0 developers are using.

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Figure 18. AES decryption through the mbedtls library

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The approach we took to finding the encrypted regions was outlined earlier and revolves around what a valid, misaligned, or null page is expected to look like. We further build on this with our decryptor by adding [Shannon entropy](#) checks on buffers of **0x1000** bytes in size. Any buffer that has a very high level (≥ 7.8), we will decrypt and then further validate the decrypted data based on what a page header constitutes.

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Taking advantage of the fact that a *.ndf* file is so "well" structured i.e., every 0x2000 bytes will always follow a guaranteed format, we can run this algorithm to identify every encrypted region within the file and successfully decrypt it. Further validation after the decryption is also required because *.ndf* file formats unsurprisingly house compressed data which can flag on our entropy scan. We need to ignore all these cases and leave them as is.

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Below is the successful output for step one. Also note, for one file the distance between encrypted regions is at **0xA00000** intervals, whereas the other is at **0x17570000** intervals. Again, the effects of the unpredictable nature of malformed asynchronous I/O, which do not pose a threat anymore.

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Now that we can successfully decrypt the files, we need to account for any headers that are misaligned. We saw how to do this earlier by comparing the *PageIndex* field inside the page header. This is the index value that identifies where this particular page needs to be inside the *.ndf* file. Refer to the misaligned header on Figure 17.

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Similar to how we found all the encrypted regions, we will proceed in the same manner (excluding the Shannon entropy check this time) of validating each expected page header, and in any instances where there is a case of misalignment, we will create a new file where we correctly insert it at its expected location. We will, of course, copy over all the already valid and existing data into the new file as well. This new file will then be fully decrypted and more importantly, correctly aligned.

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Figure 19. Validating misaligned headers

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Figure 20. Before and after header alignment

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This is great and all and certainly brings us very close to fully realizing our ultimate goal, however, the data still present at the misalignment location is just that: *still present*. We need to do something about this leftover data.

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One approach is to place “dummy” headers at these locations, in the hopes they satisfy the loading of the database file. But playing the dummy roles ourselves, we opted to just null these locations. Again, we follow the same pattern of validating the headers, but this time we know there cannot be any more misalignment, so for any leftover data that we encounter we simply null that entire page, making it in effect a null/empty page. Naturally, this loses the data there but is a willing compromise to make since these entries at this state should be far and few in between compared to the enormity of the entire database file.

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Combining all three steps outlined above led to the full restoration of the MSSQL database files to the extent that was possible, even reverting their functionality back to normal in the majority of cases. Throughout our analysis, we also had an internal MSSQL subject matter expert (SME) continuously verify our undertakings and found around 7 million inconsistencies with the initial, corrupted files, give or take, down to just single thousand digits after the entirety of our restoration process was completed. Conjuring up SQL queries became possible once again, and although at DART [we prefer our KQL](#), we still carry a fondness for our SQL predecessors.

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,"body@stringLength":"24749","rawBody":"

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If only it were so easy...

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Encryption overspill and rebuilding database files

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Moving closer to the ultimate goal: successfully restoring all encrypted database files

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Now it's time to put this theory and understanding into practice and build upon this algorithm to achieve our ultimate goal: the successful restoration of all encrypted database files.

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Recovering encrypted and corrupted database files

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With the stage now set given that all known underlying issues have been exposed, we approached the problem in the following manner.

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1. Identify and decrypt (fully) any encrypted database files with our homemade decryptor
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Step 3. Process the output of step 2 and “clean up” the final remnants of leftover data from the misaligned headers

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Conclusion

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```
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In the previous blog post in this series, we provided background about our analysis of the LockBit 2.0 ransomware and described our suspicions that 'faulty crypto' was at play. In this post, we will outline the issues that the decryptor poses and how we simply cannot trust it and must remove it from any equation we intend on using to successfully decrypt these database files.

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